CHEMICAL & METALLURGICAL ENGINEERING

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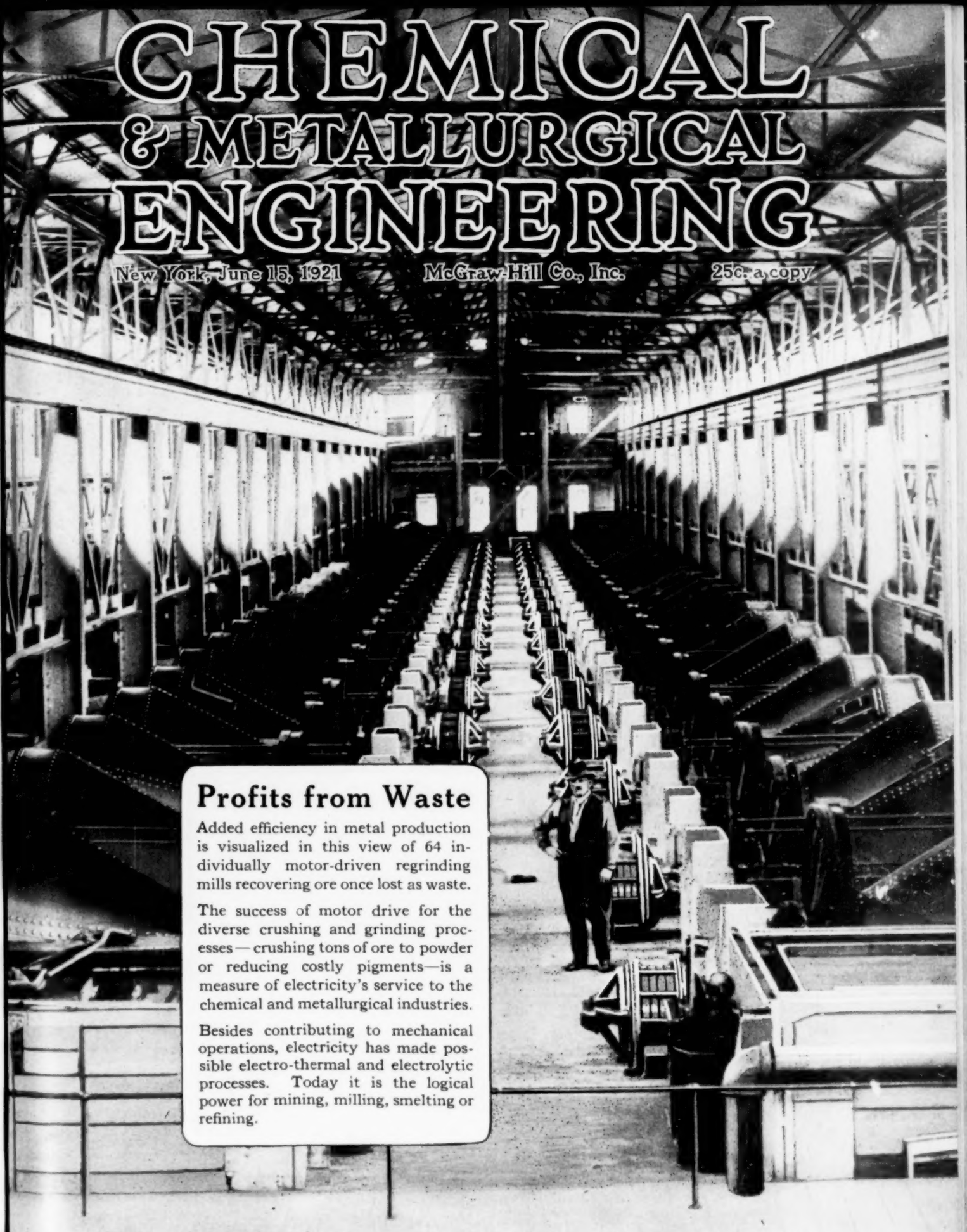

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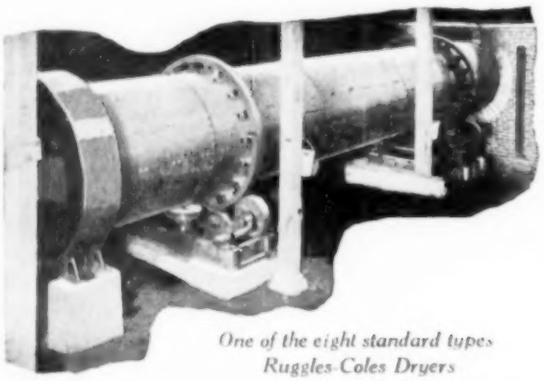

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CHEMICAL & METALLURGICAL ENGINEERING

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A New Explanation Of Hardening

IN VIEW of the importance of Messrs. JEFFRIES and ARCHER'S contribution to the theory of hardening metals, it is not necessary to explain why so large a portion of this issue is devoted to it. Metallurgists interested in ferrous or in non-ferrous metals will find it explains a great many apparently unrelated facts concerning hardness; colloid chemists will be interested in the application of their science to metallurgy; and physicists will be pleased to know that some of the first results of X-ray analysis have been put to good use in this inquiry into the nature of hardening.

A generalized conception of hardness is presented, and it is then shown how various substances and practices increase this hardness in a number of different alloys by merely interfering with a perfectly normal property of ductile crystals; the ability to deform by development of transgranular slips.

Little of the material used by JEFFRIES and ARCHER is new—that is, presented for the first time. Nearly all the facts are old and undisputed; many of the explanations have been advanced before, but failed of acceptance because of a lack of supporting evidence. For instance, ten years ago, GRENET presented a paper before the British Iron and Steel Institute, in which he said that the hardness of chilled irons, steels, brasses and bronzes was due not so much to the prevention of the transformation from the "hot stable" to the "cold stable" state, which would occur on slow cooling, as to its partial completion. Consequently hardening by quenching is due "solely to the fineness of the structure." These ideas were given little more than a respectful hearing, but many of GRENET'S critics have since come into camp with ROSENHAIN, who has exploited the properties of amorphous iron to account for the hardness of martensite. GRENET was on the right track, but he attempted no adequate explanation of why extremely fine grain causes hard metal.

BEILBY'S amorphous theory has since then become generally accepted, so that few now dispute the fact that the aggregate of minute crystals just born from austenite would possess a relatively great amount of hard amorphous metal. By X-ray analysis JEFFRIES and BAIN in America, and WESTGREN in Sweden, have but recently and definitely proved the supposition that iron in martensite is in the alpha modification and the former agrees with MCCANCE that it contains (at least in its early history) carbon in solid solution—that is, in atomic dispersion. And now JEFFRIES and ARCHER call attention to the fact that fine grain is hard because the amorphous material and random orientation of grains interfere with slip. In this way they not only establish the nature of martensite but in addition they give a rational reason for its hardness. Almost since the beginning of metallography, hardness of steels had been associated with martensite, and every effort has since been made to establish its nature, a step which SAUVEUR, twenty-five years ago, said was necessary before the riddle of quenching could be solved. If it were known just what martensite is, then one could proceed to explain why it should be hard.

But amorphous material does not grow in duralumin, for instance, on gentle annealing. Quite the opposite. Yet the hardness of the alloy is increased rather than decreased. No matter how adequately duralumin's quenched condition could be explained by amorphous boundaries surrounding fine grains, its hardening on aging must be due to another factor. MERICA and JEFFRIES were both working on this problem, but independently, and the two of them hit upon the germ of the general critical dispersion theory—that hardness is due to the dispersion of hard particles in the alloy, hard particles of sub-microscopic but correct size, neither too large nor too small. MERICA also pointed out that hardness in quenched and tempered steel could be ascribed to critically dispersed cementite.

Approaching the general theory of hardening by the "non-ferrous route" rather than from a consideration of the former theories of hardening steel, JEFFRIES and ARCHER now brilliantly show that a critical dispersion of hard particles causes maximum hardness, since it offers maximum interference to crystalline slip. And can we not agree with MERICA that such a dispersion offers as adequate a supplement to the effect of amorphous metal in hardened and tempered steel as it does in hardened and aged duralumin?

Disregarding the elegant way in which the theory covers numerous alloys by a simple conception, when applied to steel it has the virtue of ascribing hardness to the undoubted hardness of amorphous iron and cementite, rather than to the hypothetical hardness of beta iron. This undoubtedly makes for simplicity. It is to be expected that the many able men who support the claims of beta iron will not be converted over night, and their criticisms will doubtless be forthcoming and properly welcomed. Yet no one would accuse the beta iron theory, in the full flush of HOWE'S advocacy, of simplicity. Since the principal evidence that beta iron has existence is magnetic in nature, the beta iron theory must perforce explain hardness and magnetism at the same time. But when a steel is found in which the two do not vary in a proportional way, or another steel which has two or three magnetic susceptibilities for the same hardness, the beta theorists are in deep trouble. Their opponents are inclined to believe that such anomalies are best explained by the supposition that magnetism and hardness have no close relationship—in fact, are altogether different kinds of phenomena. Yet if they are discon-

nected phenomena, the beta iron theory loses its chief prop.

Perhaps, without knowing that hardness in steel could not be explained without simultaneously explaining the magnetic and electric properties, JEFFRIES and ARCHER have "gone ahead and done it"! If for nothing else, they have our congratulations for the magnetic-hardness divorce.

Tinkering With The Patent System

WHOEVER said "Eternal vigilance is the price of liberty" probably had in mind the watchfulness necessary to guard what is essentially best in any of our human institutions. Certainly it applies to the patent system of the United States which our Congressmen and Senators are wont to improve from time to time by introducing so-called reforms. In 1912 it was the Oldfield bill; in 1915 the Paige bill, and in 1921 comes Senator STANLEY with a bill to amend the Revised Statutes relating to patents. The burden of reform which all of these volunteers would load upon our patent system is some variation of a scheme to compel patentees to work their patents. The Oldfield bill proposed compulsory licensing in case an inventor was unduly slow about putting his process into effect. The Paige bill was designed to force European dyemakers to operate in the United States by causing unworked patents to lapse within two years after they were issued. Senator STANLEY'S bill would amend the Revised Statutes relating to patents with a proviso to the effect that if a patent granted to a foreigner is "not worked or put in operation so as to result in actual production . . . in the continental limits of the United States within the period of two years from the date of its issue, the United States reserves the right to license any person or persons for purposes of manufacture in the United States." Prior to these three efforts toward compulsory working, two of which were unsuccessful and the third pending, the Congress did enact a compulsory working clause in 1832, but repealed it in 1836.

Compulsory working of patents, whether on pain of having the patent canceled or being compelled to grant a license to someone else, is a device that has always appealed to lay minds. It has never been approved by the best patent counsel, nor has it been acceptable to inventors at large. Legal opinion may be summed up in the remarks of Lord MOULTON, who, in discussing the British compulsory working act of 1907, said: "I think it is not only mischievous, it is also idiotic. It is one of those cases which are growing to be common, where the layman rushes into legislation with little or no acquaintance with the subject on which he is legislating. Knowledge has gone so far that the layman cannot keep up with the technical knowledge of a subject, even in politics. In my opinion, it would have been impossible for any man who understood this matter to devise the present legislation."

We respectfully commend Lord MOULTON'S opinion to Senator STANLEY and his colleagues and offer in addition a few arguments for defeat of the proposed legislation.

It is reported that Senator STANLEY'S avowed purpose in advocating this measure is to prevent a situation such as arose at the outbreak of the war when the United States was cut off from supplies of German dyes. Presumably he believes that a compulsory licensing clause, which is in effect a compulsory working clause, would result in German manufacture in this country under German-owned United States patents. As Dr. B. C. HESSE pointed out in great detail in an address before the Rochester Section of the American Chemical Society in October, 1915, compulsory working would not create a dye industry. He showed also that compulsory working has been ineffective in the principal foreign countries and that some of those countries have entered into a mutual understanding whereby the clause is not enforced against their respective citizens. Further, Senator STANLEY'S plan would force German capital to manufacture in this country, thus promoting that "peaceful penetration" of industry which we found so objectionable when we went to war. It is true that the Stanley compulsory licensing clause applies only to foreign owners of United States patents; but to enforce it against them would encourage advocates of the idea to make it applicable to all United States patents, even though owned by American citizens. It requires no stretch of the imagination to see how surely such a measure would cause uncertainty on the protection afforded by a patent, and so weaken that protection that patents would have diminishing attraction for capital. The market for inventions would be decreased and the incentive of inventors proportionately reduced. And since the prime object of our patent system is to induce men to produce inventions, we should be exceedingly careful how we hedge them about with discouraging restrictions.

Those who have had experience with the development of patents will realize that two years is a comparatively short time in which to bring many processes and products to the stage of production contemplated in Senator STANLEY'S bill. This would deter inventors from perfecting their processes; and for the same reason it would probably deter licensees, because the first licensee would have to undergo the expense of development while others might come in and take licenses and manufacture without the handicap of initial development and expense. And as for the poor inventor who is now supposed to find it difficult to bring his patent to the production stage, would he not be worse off under a scheme of compulsory licensing? If manufacturers can now buy and suppress patents, as they are popularly supposed to do, how equally simple would it be for them to delay negotiations with an inventor for two years and then demand a license. We may also raise the question as to whether the license is to be exclusive or not. Presumably not, because "the United States reserves the right to license any person or persons" for the purpose of manufacture. And if licenses are not exclusive, how generally will they be taken, seeing the difficulties that will beset the licensee who takes upon himself the burden of initial development?

We have been able merely to touch upon the obvious features of the situation that would be created under Senator STANLEY'S bill and its logical development. The situation is fraught with danger to the patent system and to the inventive propensity of the American people. We understand that the bill has been reported favorably to the Senate by the Committee on Patents. Accordingly it will be necessary to take early action if the measure is to be defeated. We shall be glad to publish further discussion of the subject.

Labor Unions And Inefficiency

WHEN one discusses the single tax he discusses it on the basis of theory, since it is not operative. When one discusses the income tax he discusses it on the basis of practicality, because we have had it for several years and can observe its operation.

When we discuss labor unions and labor unionism we naturally discuss them on the basis of what we see. There is no occasion to consider theories or ideals regarding labor unionism because any theories entitled to consideration have had an opportunity to work out in practice. The labor union movement is not new. It is not because there has been insufficient time that only between 10 and 15 per cent of the workers are organized and between 85 and 90 per cent are left unorganized. If labor unionism as we see it involves inefficiency and injustice, it must bear the blame.

If we are investigating a species of plant, we observe where it grows, study its habitat and eventually determine the surroundings under which it will or will not grow. We can study mental inclinations in the same manner. In certain circumstances men tend to grow avaricious. In certain surroundings religious aspirations are aroused. Associated with certain persons one becomes ambitious to wear the most tasty neckties, while in association with a certain other kind of men thoughts about neckties do not thrive and the desire to be able to stick on a bronco's back has a vigorous growth.

The method is strictly applicable to a study of labor unionism. What is the favorite habitat of labor unions? Where do they thrive? Of the total enrollment in labor unions in the United States one finds that a very high percentage of the membership is included in three categories: (1) The United Mine Workers, whose members mine bituminous coal and anthracite; (2) the building trades; (3) the steam railroads and trolley lines. Outside of these three categories unionism is practically insignificant. The percentage of all unionism that is comprised in these three categories is very high, and the percentage of disturbance to the general industrial and economic situation caused by the unions in these particular lines is higher still.

Here, then, we have the favorite habitats discovered beyond peradventure of doubt. Whether studying a variety of plant or studying labor unionism, the investigator next proceeds to inquire whether there is anything peculiar about the discovered habitats that differentiate them from other places. No difficulty whatever is encountered in differentiating. Strikes in these lines of activity are in essence directed against the general public rather than against the proximate employer. In a trolley strike in a large town, which has the more patience, the public service corporation or the public that must foot it? In a six-day strike, who would suffer the more, the shareholders of the Pennsylvania Railroad Company or the patrons of the railroad? Or in an office building, the contractor whose margin is in a measure a percentage of the wages paid or the owner who has money tied up and wants to be ready for the office-leasing season? That is one kind of habitat where unionism thrives. The other is where a strike or wage disagreement is not disadvantageous to the employer. Time after time in the coal industry it has been found that consumers were stocked with coal in anticipation of a suspension of mining on the biennial April 1 and the operators needed a suspension to permit the consumption of stocks so that damaging competition would be averted.

In all these cases we find inefficiency, the workman not doing the full amount of work he should do in a day, to do his share toward bearing the total burden of the work of society.

Promotion in Technical Positions

THE chemical profession generally will congratulate Dr. A. C. FIELDNER on his well-deserved appointment as director of the Pittsburgh Station of the Bureau of Mines. This is a recognition of Dr. FIELDNER'S ability as an investigator and as a director of investigations. It is to be hoped that Dr. FIELDNER'S new responsibilities will not weigh so heavily upon his hands as to prevent continuance of his work in the field of fuel investigations. The contributions which have come from his organization have been notable, and it would be a great loss if purely administrative and executive duties were permitted to interfere with his further active participation in this invaluable scientific work. Both in the Government and elsewhere there is too much of a tendency to place upon such men the burden of administrative responsibility which interferes with the work they are so well fitted by training and experience to carry through. It is often quite simple to secure for this administrative work much less experienced and less valuable men who, though capable in this particular, are not themselves investigators, either by temperament or training. It is very fortunate that the bureau recognizes this fact and plans to give Dr. FIELDNER such assistance as we hope will prevent unduly burdening him with correspondence and other details that always beset the chief of a large organization.

Our industrial organizations of technical sort, though striving for commercial efficiency, sometimes have not been as willing as they should to be efficient in such matters as this. If the only way in which the chief chemist, the chief metallurgist or other director of investigations can advance himself within a company is by assuming executive responsibilities, it is not strange that he seeks such position. Especially if the difference in salary between the purely executive position and the position in charge of research is large do we find this tendency to change from science into the commercial branches of the organization. It is certainly false economy to permit a man who has demonstrated his ability in research and development work to become a slave to routine. He may succeed at it, though this is by no means sure, but in any event the company will lose if such change is made. Even at the risk of paying the so-called subordinate men more than the executive head it may be worth while to keep successful research men in the field of their specialties. New developments which they produce may not save as much in a single year as would a valuable administrative decision or change in operating plan, but the improvements thus achieved are capitalized for all future time. In fact, without them the corporation may fall in the race for commercial supremacy distinctly behind its competitors in technical method or value of product. It is best by all means to keep each scientific man in the job for which his training and experience best fits him, even though the salary roll may look a bit unbalanced.

Readers' Views and Comments

Production of Pure Platinum

To the Editor of Chemical & Metallurgical Engineering

SIR:—I notice in the edition of your magazine dated April 20, 1921, on page 696, you mention that the Bureau of Standards has recently succeeded in producing platinum of higher purity than any obtainable from other platinum dealers, and also that Heræus' platinum has long been accepted as standard. It is also stated that this pure platinum has been melted in lime.

I would mention that the firm of Johnson, Matthey & Co., Ltd., of London, has for many years produced pure platinum, as I can attest from forty-seven years' experience with the firm. The platinum produced by it has passed all tests and is pure, but to produce it pure it is not necessary to melt it as you state, and the slightest trace of lime, if found, is not caused by melting in lime.

For your general information, I would say that G. Matthey, F.R.S., produced pure platinum by carefully refining metal, precipitating, washing in pure water free from Ca, pressing the powder into a solid ingot by hydraulic pressure, after which it was heated in a closed muffle, placed under a powerful drop hammer, and welded together. As is generally known, platinum is one of the easiest metals to weld. My experience is that if you want pure platinum do not melt it unless you are looking for trouble. Obviously if alloys of platinum are wanted, they must be melted, but the high temperature required causes (slight) contamination with the refractories used.

I may say that I am not depreciating the work of W. C. Heræus in the production of pure platinum.

Maidstone Road, Bound's Green, London, N. 11. H. A. KENT.

To the Editor of Chemical & Metallurgical Engineering

SIR:—I have read with interest the comments of H. A. Kent, of London, with reference to the brief press notice that appeared in your journal on the production of very pure platinum.

Mr. Wichers' paper in now in press and will appear shortly in the *Journal of the American Chemical Society*. In this paper there is given the experimental evidence in support of the statement that the platinum produced by the methods there described is of higher purity than any samples of Heræus platinum that we have been able to obtain or about which we have been able to find any published data. The platinum wire produced by Mr. Wichers was compared with a number of samples of Heræus platinum wire, selected from among the purest samples that we have been able to obtain from that maker during the past fifteen years.

I may add that Mr. Wichers did not compare the wire produced by his method of purification directly with a sample of Johnson, Matthey & Co. platinum wire, but no samples of wire that have thus far come into our possession from the latter source have quite equalled in purity the purest Heræus platinum wire. It has been found that the purer the platinum the higher its temperature coefficient of electrical resistance. For the purest Heræus platinum, the ratio of electrical resistance at 100 deg. to electrical resistance at 0 deg.—i.e., $R_{100} \div R_0$—is somewhat above 1.391. The samples of Johnson, Matthey & Co. platinum wire tested in the laboratories of the Bureau of Standards during the past fifteen years were found to give values of this ratio of about 1.386. Some specially pure samples of platinum wire furnished by Johnson, Matthey & Co. to a committee of the British Association were reported (B. A. Report 1901) to have a value equal to 1.3892. Dr. J. A. Harker in a report of the same committee (B. A. Report 1903) gives for the values of this ratio figures ranging from 1.387 to nearly 1.389. It seems very probable, therefore, that the Johnson, Matthey & Co. platinum is not quite so pure as is the Heræus platinum.

In another paper, now in preparation, it will be shown that Johnson, Matthey & Co. platinum, as furnished for high temperature thermocouples, contains *relatively* large amounts of calcium as compared with Heræus platinum and very much larger amounts than the platinum refined in the laboratory of the Bureau of Standards. The amount of calcium can be very greatly reduced by merely melting on lime under proper conditions.

I may add, in conclusion, that Mr. Wichers and his associates, C. O. Fairchild and W. F. Meggers, have also obtained thermoelectric and spectroscopic evidence that the wire which he has produced is purer than any of the samples with which it has been compared.

W. F. HILLEBRAND,
Chief Chemist, Bureau of Standards.

The Vapor Compression System of Evaporation

To the Editor of Chemical & Metallurgical Engineering

SIR:—May I offer the following information relative to Mr. Carlsson's article on "The Vapor Compression System of Evaporation" on pages 645-647 of your issue of April 13?

In introducing his subject, he suggests that multiple-effect evaporators have decided weak points both from an economical as well as a technical standpoint and throughout his article gives the impression that fuel must be primarily consumed to operate such equipment. As a chemical engineer, having had over ten years' experience in the design and operation of evaporators from the coil type to the film type, may I state that over 95 per cent of the multiple-effect evaporators operating today are using exhaust steam in whole or in part? It is first used in prime movers and fed to the vacuum plants at pressures up to 5 lb. per sq.in.

In actual practice with a film type of evaporator my own records over a long period show 2.8 lb. of water evaporated per lb. of exhaust steam used in a triple-effect machine having a capacity of 10,000 lb. per hour. This evaporation was obtained without the use of a preheater or utilizing hot outgoing condensate or vapors; with such arrangements the heat efficiency would have been increased.

Is it not rather a sweeping statement to say that "many suggestions of new evaporation methods made in recent years have failed until quite recently"? I can specifically state a number of cases where evaporation improvements have been carried out within the past ten years. For instance, the advent of the film evaporator resulted in such a compact design that it

was possible to superimpose three effects, thus making a self-contained triple-effect evaporator.

Mention that the Swiss firm began marketing the "Autovapor" evaporator only in 1918 places that firm far behind the pioneers in this system of evaporation utilizing vapor compression principles. As far back as 1906 experiments were made with a Simplex film evaporator in which live steam injector was embodied, which sucked back and compressed the vapor coming from the liquor. This compressed vapor and ingoing steam was then passed back to the calandria to perform further work. This in itself utilized the principle of vapor compression, although it was not carried to any elaborate conclusion. Prior to 1914 a technochemical concern built a vapor compression evaporator plant in London. This was known as the Söderlund-Boberg evaporator and has priority in development work over the "Autovapor," if it is not the same equipment.

I consider that the "Autovapor" efficiency figures quoted are on the high side, particularly if they were obtained with the design of equipment shown. It is well known in evaporator work that, consistent with the class of liquid being handled, the higher the temperature difference between the heating medium and liquid being heated the higher the transmission factor per square foot effective heating surface. For standard vacuum evaporator work, using exhaust steam, this temperature difference varies from 30 to 100 deg. F. Such a difference as 30 deg. F. would not be economically permissible with a vapor compression system, as the power and capital expended to produce this difference would overbalance any conservation of heat thereby gained. To make any vapor pressure system economically effective it is necessary to operate with low temperature differences, and this means increased heating surface. Using a coil type of pan, the heating surface would be so large for a normal commercial unit that the initial cost would be prohibitive.

Why distilled water (or condensed vapor) from the "Autovapor" is purer than that obtained from vacuum evaporators is not explained and is not perfectly clear.

I take exception to the balance sheets submitted, in that it is assumed the steam used is primarily produced for this purpose, where, as before mentioned, the majority of plants use exhaust steam. Again, the figure of 2 lb. of water evaporated per pound of steam for a triple effect is too low, and should be 2.8 for a film type of plant, which is the most modern type of vacuum evaporator. The figure of 8 hp. for a condensate pump designed for a triple-effect evaporator of 2,200 lb. capacity has evidently been taken from a textbook. The actual practice figure is nearer 2 hp.

I am glad the writer indicates the shortcomings of this system, in that "when dealing with concentrated solutions, the conditions are not so favorable, because the boiling points of the solutions are higher than those of solvents." This means that it is too costly to compress the vapor to a point where the temperature difference would produce a concentrated solution.

A triple-effect film evaporator will treat any and all solutions, concentrating up to 30 deg. Bé. continuously, evaporating 2.8 lb. of water for 1 lb. of exhaust steam and with a mechanical expenditure of 1.7 hp. per 2,000 lb. evaporated, with no high-speed or complicated mechanism requiring skilled supervision.

It will be many years before a compression system of evaporation will be able to compete with the film evaporator in the average industry, and electrical or water power will have to be at low cost, with a perfected fool-proof compressor, made sufficiently rugged to warrant unskilled attention. The capital cost and overhead, involving skilled attention for compressor and evaporator, is not included in Mr. Carlsson's balance sheet.

BURTON DUNGLINSON.

Chicago, Ill.

To the Editor of Chemical & Metallurgical Engineering

SIR:—My statement, in my article on "The Vapor Compression System of Evaporation" in your issue of April 13, that the multiple-effect system has weak points from economical and technical points of view, refers to the fact that condensers in general have to be installed with the result that a certain amount of latent heat is wasted. Furthermore, having rather small quantities of water to evaporate, it is very expensive to install such a huge aggregate to get the desired efficiency, the Autovapor having only one container with its compressor and motor with which a good efficiency is obtained. The latter installation does not require more labor than the multiple-effect system. With larger apparatus using exhaust steam in evaporation, the calculation on page 647, second column, shows that the compression system is able to compete favorably with a multiple-effect system. Throughout the article the calculations are based upon installations having a capacity of 2,200 lb. A triple effect under those conditions does not have greater efficiency. For larger capacities both of the methods have greater efficiency factors and results of a comparison will still hold.

In regard to my "sweeping statement" I might say that it referred to different compression methods tried in the past and Mr. Dunglinson has mentioned two which he knows have been a failure or at least had but a very limited application. As far as my experience goes, this is true. This pioneer work, however, I am certain the manufacturers of the Autovapor appreciate and I don't think they claim to be the first ones.

As a matter of fact the Söderlund-Boberg people confine in their English patent the use of the machines to solutions similar to sulphite cellulose waste liquor.

The Autovapor in its perfection now accomplished is running with quite different heat head than the Söderlund-Boberg, in fact it is similar to that of multiple-effect evaporators due to the development of the high-speed turbine compressor. This machine is able to handle the vapor in a very satisfactory manner. As a matter of fact, the point in this system is the compressor and its accomplishment has been such that the vapor compression system is economically effective without operating with low temperature difference and too much increased heat surfaces.

The efficiency figures are not on the high side. They are obtained in real practice and with a small installation. In this connection I would like to correct the figure 19.3 on page 647, line 48, which ought to be 42.7. With greater units higher results are obtained.

I have a list of twenty-five installations of this apparatus in Europe showing that the Autovapor has passed its "childhood." I think this fact is the best answer to Mr. Dunglinson's statement of the probable shortcoming on the part of the Autovapor system.

That the compressor really is fool-proof and that the expenses for capital cost and overhead are not prohibitive do not require discussion.

GUSTAV CARLSSON.

Niagara Falls, N. Y.

Italian Chemical Industries

FROM OUR SPECIAL CORRESPONDENT

GENOA, Italy, May 20, 1921.

DURING the last few weeks the crisis in the Italian chemical industries has been aggravated by the elections just finished, by the shortage of American and English coal, and by the upset conditions of labor. Only a few works, especially those producing the common acids, alkalis and fertilizers, can continue their work as usual, whereas all those producing the finer chemicals have either closed or continue under great difficulty, working only for four days a week with reduced hours. In the metallurgical and engineering industries only those concerns which have to supply materials to the Italian state railways, to the shipyards and to the hydro-electric plants can be kept in running condition.

FOREIGN EXCHANGE SINKS FURTHER

The foreign exchange, especially in the cases of the United States dollar, of the English pound and of the Swiss and French franc, has sunk considerably during the past month, while no change followed through a renewed business intensity with German-speaking countries and some of the new Balkan states. These conditions and the absence of demand brought a further reduction in prices for most chemicals, metals, drugs, essences and other products, causing great losses to the producers and merchants. The exportation of Sicilian products has come to a sudden standstill owing to the rise in price when sold for foreign currencies. A new law authorizing the exportation against payments in Italian lire was issued, and this, it is expected, will facilitate a resumption of foreign traffic.

ITALIAN INDUSTRIALS MEET

With the view of helping the future of the chemical industries and other Italian industries the principal Italian industrials met at Rome under the auspices of the Minister of Finances to discuss the difficulties through which the said industries are passing, and demonstrate the utter impossibility of continuing with the present fiscal taxes, which are gradually ruining all industrial enterprise.

WAGE IMPROVEMENT IN THE CHEMICAL INDUSTRY

After several sittings and discussions, the troubles between the Italian chemical workmen and their employers were finally settled. Through the accord reached the wages will be increased 0.50 lire for the men, and 0.40 lire for the women, boys and girls, dating back to Feb. 1, 1921. From this arrangement are excluded the dye works of Cengio, Rho, Cesano Maderno and Turro, and companies that have national agreements.

ITALIAN FERTILIZERS

The demand for immediate delivery of fertilizers is nearly stopped, owing to the advanced season. Contracts for July, August and September delivery of important amounts of superphosphate were concluded recently, but the prices made in this instance are much below those of the market quotations.

A NEW INDUSTRIAL FAIR

A new industrial fair, occupying an area of 25,000 sq.m. and arranged for accommodating over three thousand exhibitors, was inaugurated in the City of Milan. The leading concerns manufacturing drugs, essences and metallurgical products in Italy and other countries were represented. Besides the usual world-known products, new raw materials for producing refreshing drinks, pharmaceutical products and essences were noted. German-speaking countries have taken advantage of this exhibition to advertise their produce in all branches and to open new business relations not only in Italy but also elsewhere.

NEW WATER-POWER AND HYDRO-ELECTRIC DEVELOPMENTS IN ITALY

Further developments took place during the last five weeks in Italian hydro-electric plants. The erection of an important plant at Mazé has just been started. The waters of the River Dora with 60-m. head will be diverted, through special canals, to a series of turbines. The electric power is to be utilized in the neighborhood. The Italian Council of Ministers has approved special arrangements to guarantee the financing of the erection of new hydro-electric plants. A law was published constituting the Autonomous Association for the Development of Hydraulic Power and New Waterway along the River Adige to the Lake of Garda. This would prove greatly beneficial to the provinces of Verona, Mantova, Modena, Bologna and Trento. The new concern will have an unlimited capital, being financed by some of the most important banks, and will use the hydraulic power for light, for electrification of the railways and for motive power in the industries of these provinces. The construction of the second largest hydro-electric plant in the world (the Niagara Falls plant being the largest) not far from the City of Venice has already been started. Two thousand five hundred workpeople are now employed on the work of building canals by which a great portion of the waters of the River Piave will be caused to run into a huge distribution basin leading to the power plant. This work is pushed simultaneously with that of the enlargement of the port of Venice.

COAL SCARCITY IN ITALY

A great famine of American and English coal is being experienced, owing to the suspension of all deliveries from England and to the fact that few ships have reached Italy from the United States. This has brought up the prices very strongly for the rare lots of the coal still available. To help matters as much as possible the Italian state railways have further lowered the prices of the German war reparation coal which they offer for industrial purposes and for consumption in the ports. Not all the consumers of coal could take advantage of such offer owing to their plants requiring better qualities of coal, such as that which can only be obtained from the United States and from England.

ITALIAN ARTIFICIAL DYE INDUSTRY

The Italian Minister of Industry is studying the application of customs tariffs for favoring the Italian artificial dye industry. This industry, born principally during the war, has now four large works in Lombardy and Liguria, and employs thousands of workmen. The Italian customs, up to the moment of writing, did not place any importation duty on dyestuffs, nor are these considered among the products of prohibited importation. This tariff encounters resistance on the part of producers of colored fabrics and yarns, who wish to get the products they use at as low a price as possible.

Survey of Chemical Engineering Education

Summary of Questionnaire Showing Curriculum of 78 Institutions—Courses Taught Include 49 in Chemistry, 15 in Physics, 10 in Mathematics, 9 in Mechanics, 6 in Engineering Elements, 31 in Mechanical, 6 in Civil, 8 in Electrical, 6 in Mining, 14 in Sanitary, 3 in Safety, 14 in Industrial, 11 in English, 6 in Languages and 23 Miscellaneous

THE committee on chemical engineering education of the American Institute of Chemical Engineers, composed of Joseph H. James, Ralph H. McKee, Charles L. Reese, Albert W. Smith and James R. Withrow, with Arthur D. Little as chairman, has initiated a survey of chemical engineering courses in seventy-eight institutions in the United States, this being the entire number known to the committee as offering such courses. Through the co-operation of the presidents and heads of departments in these institutions it has been possible to tabulate in a comparative way the apportionment of time and credit to the several subjects included in these courses, and this tabulation is here presented, primarily as a report of progress and for the purpose of precipitating the discussion which the extraordinary variation in such weighting would seem to justify.

Multiplicity of Subjects Included

The first feature of outstanding significance is, of course, the remarkable multiplicity of subjects that have come to be included in these courses. The next of important interest is perhaps the widely divergent views as to the relative values assigned to the same subjects in the different institutions. There appears also to be a tendency to multiply courses by the subdivision of fundamental subjects into minor courses that might conceivably to better advantage be tied together into a major course.

Need of Standardization

All this would seem to point quite clearly to an imperative need of standardization of courses of chemical engineering as taught in our American institutions. To what extent, however, this may be desirable, how it may best be accomplished, or whether a complete recasting of courses along the lines suggested by the case system or the School of Chemical Engineering Practice of the Massachusetts Institute of Technology is the indicated remedy, the committee at this time expresses no opinion, preferring to have the benefit of the views and discussion which it is hoped the publication of this tabulation may provoke.

Any communications relative to the subject will be especially welcomed and will receive careful consideration if addressed to Dr. Arthur D. Little, chairman of the committee, at 30 Charles River Road, Cambridge 39, Mass.

The table is being published in advance of the committee report to the society at the Detroit meeting next week to enable proper study prior to discussion there. The views presented at the meeting will be published in connection with the report of the meeting or separately in a subsequent number. Those who wish to forward written communications to the meeting expressing their views should send them to Dr. John C. Olsen, secretary, Statler Hotel, Detroit, in time for presentation on Monday.

Explanation of the Tables

Where the parenthetical numbers (5) and (6) are used in connection with the hours devoted to a subject, five- and six-year curriculums are indicated. The footnotes indicated by single, double, triple and quadruple crosses are to be found under Remarks, lines 222-226 in the respective columns in which they occur.

The forty-nine headings under chemistry show a tendency for a few institutions to offer a specialty such as sugar at Louisiana and paper at Maine. It is also an indication of the limit of possibilities of chemical instruction and how much must be left for the student to dig out for himself after graduation. Irish history seems to be the joker, no institutions giving credits or devoting hours to it, but the committee must have included it with full knowledge that no chemical engineer can get along in a manufacturing plant without knowing the ways of the Irish foremen.

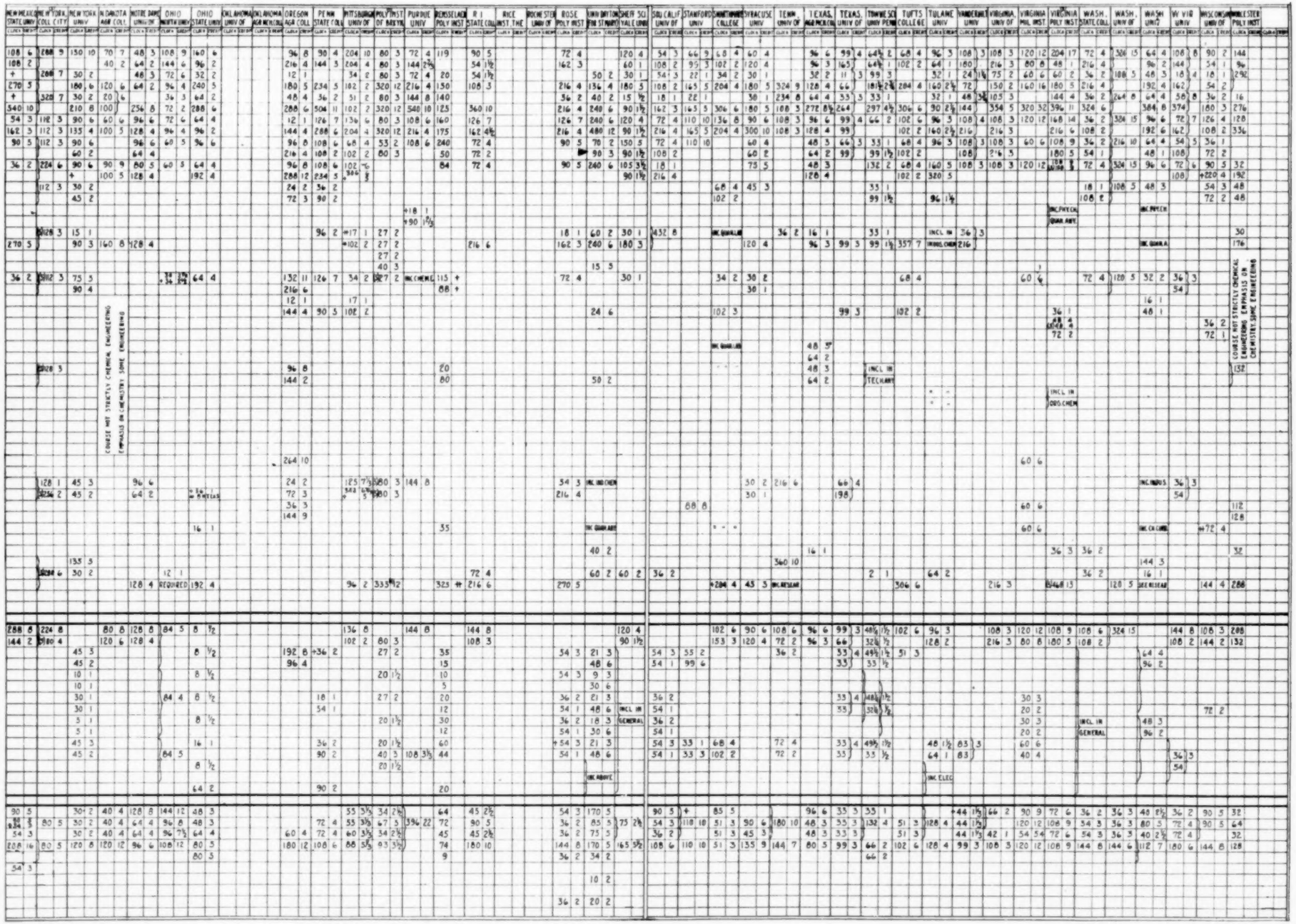
Chemical Engineering Laboratory Facilities Meager

Only twenty-seven out of the seventy-eight institutions included in the report offer any chemical engineering laboratory facilities or instruction. In any other field of engineering education this would be inconceivable. However, the types of equipment that are available for student work are so very limited in variety and size that it is an open question whether equipment operation can be studied anywhere except in a manufacturing plant. The large-scale evaporator station at the University of Michigan shows the possibilities for engineering research and design data determinations within the province of the university. Other fields of activity such as distillation, reduction and grading of solids might be similarly intensively developed on a large scale, if the commercial interests involved could be persuaded to co-operate with the institution having the best fitted staff to take up the work.

The large number of white spaces under Industrial Engineering again emphasizes the fact that the student going into a plant organization has to realize that he has just graduated into being his own teacher. He must be able to create a course for his own study on production engineering, costs, operation planning, industrial relations, commercial specifications, estimates and contracts whenever there is a demand, if he is ever to quit the drawing board and be an executive.

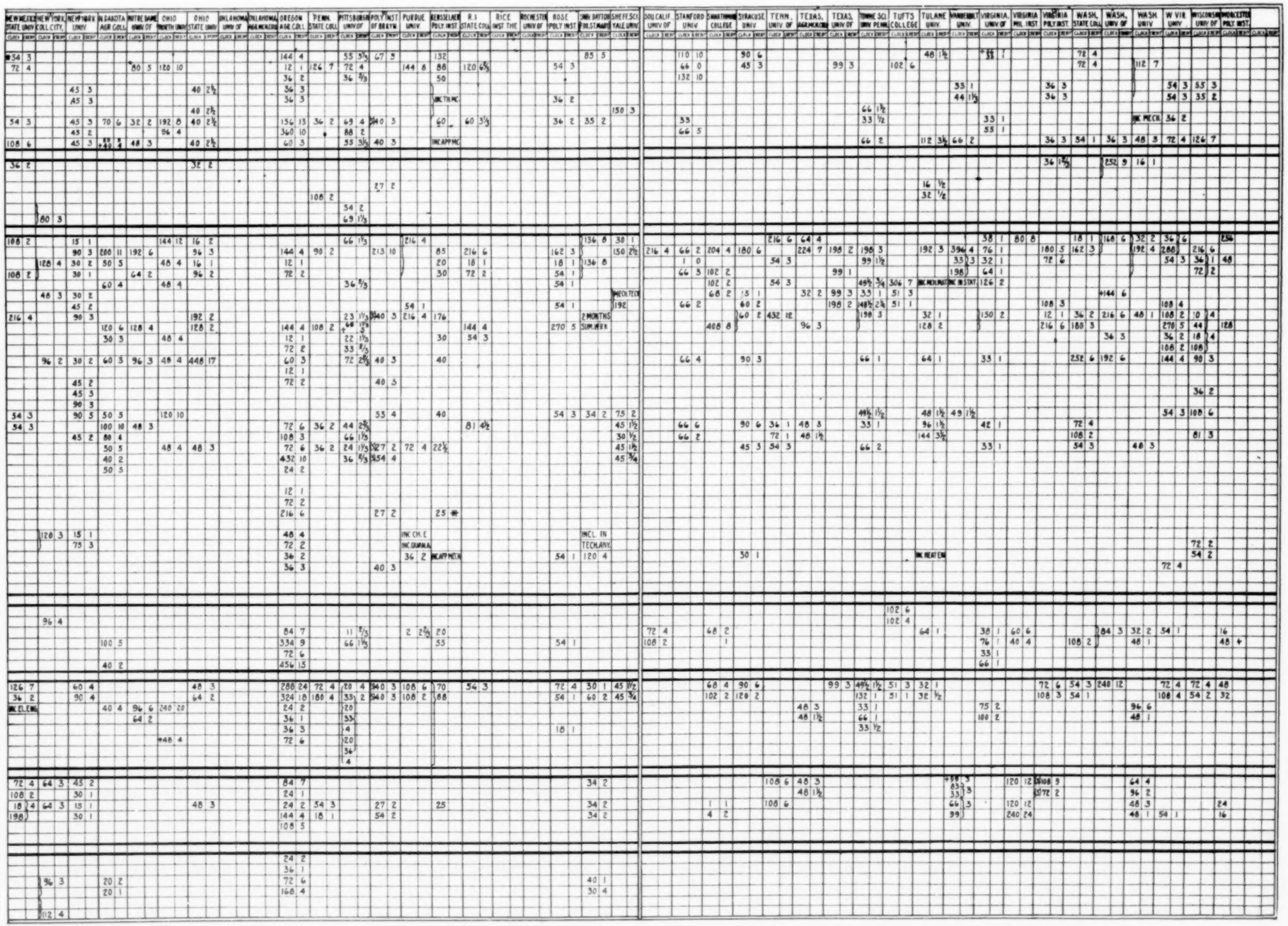
Undoubtedly there are errors, some even so colossal as omitting the name of some very important institution such as the University of Illinois or physical chemistry from the curriculum of Boston Tech. We shall be glad to publish all corrections received and forward them to the committee.

CHEMICAL ENGINEERING 1920-1921	ALABAMA POLY INST	ARKANSAS UNIV OF	ARMOUR INST TECH	BUCKNELL UNIV	CALIF. UNIV OF	CALIF INST TECH	CARNEGIE INST TECH	CASE SCH OF APP SCI	CATHOLIC UNIV AMER	CINC UNIV OF	CLEMSON AGR COLL	COLORADO UNIV OF	COLUMBIA UNIV	DELAWARE COLLEGE	DRAKE UNIV	DETROIT UNIV OF	FLORIDA UNIV OF	GEO WASH UNIV	GEORGIA SCH TECH	HARVARD UNIV	IDAHO UNIV OF	IOWA STATE COLL	IOWA STATE UNIV	KANSAS UNIV OF	LAFAYETTE COLLEGE	LEHIGH UNIV	LOUISIANA STATE UNIV	MAINE UNIV OF	MARQUETTE UNIV	MARYLAND UNIV OF	MASS INST TECH	MICHIGAN UNIV OF	MICHIGAN AGR COLL	MINN UNIV OF	MISSOURI UNIV OF	MONTANA COLL AGR & MECH	NEW HAMP COLL AGR & MECH
CHEMISTRY																																					
1 General Inorganic		144 12		72 6	90 6	91 8	156 13	102 6	96 3	99 13	111 3	144 12	90 12	68 4	108 9	66 6	108 5	90 6	160	136	69 4	66 6	108 6	54 3	136 6	160 10	180 5	108 3	72 4	54 6	72 6	150 7	64 5	48 4	138 6	96 6	72 6	108 9
2 General Inorganic Lab		144 4		96 4	120 4	138 12	216 6	136 4	160 3	112 6	65 2½	108 3	180		144 4	132 6	144 2	270 6	64	102	192 4	66 2	108 2	72 2	136 4	64 4	144 2	144 2	144 4	72 4	216 6	120 4	90	24 1	92 4	64 2	120 4	
3 Qualitative Analysis		36 3	90	10 2		35 3	12 1	57 3			24 1	108 9	120 11	204 6	24 2	11 1	36 1		32	68	16 1	21 2		36 2	34 2	32 2	18 1½	18 1½	36 2		12 1	30 5	48 5	12 1	66 6		48 4	24 6
4 Qualitative Analysis Lab		72 2	54	96 3		150 13	108 3	210 4	32 -	88 7	84 2	216 6	105		144 4	66 3	150 1½	270 6	192	316	144 3	63 2	108 2	108 3	102 2	128 8	108	108	180 4	48 3	108 3	180 30	90	72 3	132 4	96 3	150 5	156
5 Quantitative Analysis		48 4	108	96 6	30 2	44 4	12 1	122 7	32 -	50 6	37 6	144 12	30 2		60 5	22 2	36 1		96	102	16 1	54½ 5	36 2	18 1	102 6	56 6	18 1½	18 1½	36 2		48 4	40 1⅓	48 8	24 2	46 4	1½	48 4	
6 Quantitative Analysis Lab		216 6	324	128 4	180 4	154 14	72 2	642 12	182 4	172 12	113 4	324 9	180 6	204 6	396 11	132 6	216 2	360 8	456	204	144 3	195 6	324 6	432 9	714 14	432 27	108	108	288 8	108 6	360 10	210 7	225	144 6	230 3	1½	180 6	300 12
7 Organic		72 6	108	96 6	53 3	102 9	72 6	153 9	96 3	81 12	74 2	144 12	90 6	102 6	60 5	33 3	108 3	120 8	96	153	80 5	97½ 9	108 6	108 6	68 4	112 7	108 3	103 3	108 6	72 8	72 6	110 3⅔	128 10	48 4	136 9	48 3	108 9	96 8
8 Organic Lab		144 4	216	128 4	270 6	204 18	216 6	153 3	182 3	172 9	74 1	108 3	90 6	204 6	144 4	44 2	144 2	450 10	96	308	144 3	195 6	216 4	216 4	102 2	288 18	360 5	144 2	144 4	72 4	216 6	150 7½	180	96 4	138 4	64 2	180 6	48 4
9 Physical		72 6	54	96 6	60 4		36 3	102 6	96 3	40 5	50 2	144 12	90 6	102 6			72 2	60 4	77	153	64 4	96 6	108 6	54 3	68 4	80 5	108 3	36 1	108 6	18 2	72 6		48 3	36 3	136 9	32 2	72 6	108 9
10 Physical Lab		144 4		128 4	135 3		108 3	51 1	182 3	60 3	50 1	144 12	90 3				72 1		24	204	96 2	96 2	216 4	108 2	34 0	96 6			72 2	36 2	72 2			72 3	204 6	144 3	120 4	24 2
11 Industrial		60 5	216	64 4	60 6	69 6	72 6	116 7	96 3	175 10	74 2	48 6	48 3	102 6	108 9	88 11	108 3		62	102	64 4	162½ 15	108 6	108 6	102 6	80 8	72 2	72 2	108 6	27 3	72 6	60 3		120 10	115 10	196 6	36 3	108 9
12 Industrial Lab			432	64 2				112 6				108 3	90 3			132 6		270 6			96 2	+	+8 DAYS			112 7		+		144 4	100 10		312 13	220 6		60 2	
13 Electrochemistry		36 3	36				48 4	48 3		35 5	24 2		30 2	85 5								21 2	54 3	54 3		16 1			54 3	18 2	34 3			34 3	138 6 APPROVED	132 2	60 5	
14 Electrochemistry Lab		72 2	72	INC PHYCHEM						52 3	24 1		45 1½	34 1								63 2	108 2	108 2		48 3			36 2	36 1				48 2	138 2	196 3		
15 Thermochemistry																						INCLUDED IN PHYSICAL							27 3								
16 Thermochemistry Lab																																					
17 Technical Analysis							60 5		32 -						INC QUANT ANALYSIS	66 6						10 1				16 1	268 4	286 4	36 2						24 2	100 4
18 Technical Analysis Lab						72 6	360 12		230 5	52 3				204 6							288 6	90 3	162 3			144 9			286 8	36 1½				72 3		60 2	325 13
19 Microscopic Analysis																						INCL IN TECH ANT															
20 Microscopic Analysis Lab																						INC TECHNOL															
21 Metallurgy			144	32 2				93 6	32 1	30 4	74 2		75 5		34 3	33 3		30 2	32					144 8	34 2	140 10			54 3	36 4		48 2	24 2			36 3	
22 Metallurgy Lab			288	32 1						38 2												AND BRASS			51 0	16 1			108 2				144 6			60 2	
23 Assaying																					144 3			9 ½		32 2			72 2							12 1	
24 Assaying Lab								39 1					90 3											144 2½		176 11				36 1						60 2	
25 Metallography										25 5		36 3	45 3																								
26 Metallography Lab										62 5			30 2																								
27 Petroleum Technology																						INC INDUS CH															
28 Petroleum Technology Lab																																					
29 Food Products								INC QUAN ANAL							36 3	38½ 1										16 1												
30 Food Products Lab															72 2	366 3										80 3											
31 Sugar																												5108 3									
32 Sugar Lab																												5360 5									
33 Colloid						35 3							30 2									INC INDUS CH								36 3							
34 Colloid Lab																						AND PHYS CH								36 1							
35 Cellulose																													90 3								
36 Cellulose Lab																																					
37 Agricultural				32 2																								72 2								
38 Ceramic																																					
39 Chemical Engineering					15 1	88 8	72 6	34 2	128 3	30 6		60 5				38½ 1						94 9				INC IND CHEM					130 5	256 17		128 6		36 3	
40 Chemical Engineering Lab				256 6	180 4	INC RESEARCH	60 1½	180 4	574 8	180 3		72 2	80 2½		48 4	366 5	180 5						162 3				CHEM						315			90 3	
41 Chemical Principles					15 1	138 12																									150 7						
42 Chemical Principles Lab					60 2	102 9																									36 12						
43 Chemical Calculations								23 1							INC DIAGRAMS	66 6						INC CALCULATIONS		34 2		36 1	36 1			72 6				23 2			
44 Chemical Philosophy																																					
45 History of Chemistry		36 3																				INC SEMINAR				16 1											
46 Chemical Research					180 4	319 29										320 5		+				INC THESIS	5432 8			96 6										340 12	
47 Chemical Seminar					WORK STU			31 2				12 1				11 1						53 5												23		188 9		
48 Chemical Theses (Lab & Rep)			54					360 7	96 3	312 6	72 3		90 3						240		192 4	154½ 5		160 3				98 3			240 13½		240 10	325 15	348 3		
49 Biochemistry																																					
PHYSICS																																					
50 General		108 9	180	96 6	150 10	34 3		153 9	96 -	90 12	185 5	180 15	90 6		108 9	77 7	180 5	90 6	176	108	96 6	130 12	180 10	144 8	102 6		108 3	108 3	144 8			180 6	160 10	144 12		128 8	108 9	102 9
51 General Lab		72 3	108	128 4	90 2	408 36		204 4	96 5	92 5	148 2	108 3			144 6	99 4½	216 3	120 4	96	72	192 4	97½ 3	108 2	72 2	204 4		72 1	72 1	72 2			60 2	60	72 3		64 2	180 6	175 9
52 Mechanics							60 5				111 3			85 5											64 4				48 4				48 3			
53 Mechanics Lab							24 ⅔				24 1			51 1½											16 1				36 1				24 1			
54 Sound														21 1⅛											16 1											
55 Sound Lab																									16 1											
56 Heat							24 2																		32 2				48 4				48 3		24 2	
57 Heat Lab							24 ⅔						90 6	51 1⅛			INCLUDED IN GENERAL			INCLUDED IN GENERAL		INCLUDED IN GENERAL				32 2			92 10	36 1		48 2	24 1		60 2	
58 Light													55 3	21 1⅛											32 2											
59 Light Lab														17 ½											16 1											
60 Electricity				32 2			48 4						90 6	21 1¼		44 4									64 4	72 2	144 4			48 4							
61 Electricity Lab				96 3			48 1⅓							17 ½		66 3									32 2	72 1	120 1⅔			36 1							
62 Magnetism														21 1¼											16 1								48 3			
63 Magnetism Lab														17 ½											16 1								24 1			
64 Physical Measurements				128 5									45 1½			16 1½									48 3			72 2	88 5					128 5			
MATHEMATICS																																					
65 Algebra		96 8	90	80 5		24 2	60 5		32 -		159 9	72 6	45 3	85 4½	60 5	55 5			48			60 3		54 3	34 2	48 3	108 3	108 3	108 3		72 8	36 3		128 8	60 5	60 5	80 5	48 4	72 6
66 Analytical Geometry		84 7	90	80 5	150 12	66 6	60 5	88 6	32 -	120 18	60 3	60 5	45 3	102 6	60 5	55 5	108 3	54 3½	112	57	160 10	90½ 3	180 10	90 5	68 4	48 3	60 1½	60 1½	90 5	54 6	72 6			60 5	44 4	80 5	60 5	72 4
67 Trigonometry		60 5		116 1			60 5	85 5	32 5		60 3	48 4		119 5	60 5	55 5		36 1⅛	48	27		52½ 5		36 2	34 2		60 1½	60 1½	90 5	36 4	36 3			60 5	44 4		48 4	36 3
68 Calculus		120 10	144	48 3		136 12	96 8	153 9	128 4	120 18	136 8	144 12	90 6	108 6	144 12	132 12	216 5	90 6	118	96	128 8	162½ 13	216 12	90 5	102 6	128 8	180 5	180 5	90 5	90 10	72 6	96 3	128 8	168 14	175 15	160 10	138 12	144 12
69 Differential Equations				48 3			24 4						45 3			33 3						INC IN CAL													24 2	INC IN CAL
70 Computation						12 1																															
71 Slide Rule																	4 0		16			INC ENG CO														
72 Conics				16 1																																INC ABOVE
73 Vector Analysis																								204 4							30 3			44 2			
74 Mathematical Laboratory																99 6																					



CHEMICAL ENGINEERING 1920-1921	ALABAMA POLY INST.	ARKANSAS UNIV OF	ARMOUR INST TECH	BUCKNELL UNIV	CALIF UNIV OF	CALIF INST TECH	CARNEGIE INST TECH	CASE SCH OF APP SCI	CATHOLIC UNIV AMER	CINCIN UNIV OF	CLEMSON AGR COLL	COLORADO UNIV OF	COLUMBIA UNIV	DELAWARE COLLEGE	DES MOINES UNIV	DETROIT UNIV OF	FLORIDA UNIV OF
MECHANICS																	
THEORETICAL MECHANICS		144 12			90 6		48 4		64 2					102 6	120 10		126 3½
APPLIED MECHANICS			108			69 6	84 7	136 8	96 3	90 12		36 3				88 8	
APPLIED MECHANICS LAB								39 1	128 4							44 2	
STATICS										60 9			75 5				
DYNAMICS										38 5		36 3	45 3				
KINEMATICS												36 3					
HYDRAULICS			90		45 3	MC CHEM ENG					24 2	36 3	@45 3	68 4	@36 8	55 5	72 1
HYDRAULICS LAB																	72 ½
MECHANICS OF MATERIALS			90		45 3		12 1					84 7	@45 3		60 5	55 5	72 2
ELEMENTARY ENGINEERING																	
ELEMENTARY ENGINEERING																	
ELEMENTARY ENGINEERING LAB																	
EXPERIMENTAL ENGINEERING																	
EXPERIMENTAL ENGINEERING LAB																	
GENERAL ENGINEERING																	
GENERAL ENGINEERING LAB																	
MECHANICAL ENGINEERING																	
MECHANICAL DRAWING			162		90 3		24 2		32 -		@185 2½	96 8	30 4	204 6	24 2	110 5	
MECHANICAL DRAWING LAB		432 12	162	128 4		204 18	144 4	136 2	128 4	237 14	122 2	216 6	150		180 5		144 2
DESCRIPTIVE GEOMETRY			144				24 2	204 4			52 4	48 4	45 3	68 4	24 2	33 3	72 2
DESCRIPTIVE GEOMETRY LAB			108			30@ MCHE	72 2					72 2			72 2	121 5½	72 1
GRAPHICS																@88 5½	
MECHANICAL ENGINEERING		12 1	36		45 3					42 6	135 5	24 2		102 6			
MECHANICAL ENGINEERING LAB		36 1	108				72 2			35 2	99 2½	144 2				@144 8	
SHOP WORK		216 6		32 2		136 12					74 1	12 1		153 3			
SHOP WORK PRACTICE			216	96 2	60 2		144 4				74 1	36 1					324 4½
MECHANISM			54									60 5				33 3	
MECHANISM LAB												108 3				44 2	
MACHINE DESIGN			198		60 3	33 3	36 3					108 5	@60 *4		48 4	66 3	108 1½
MACHINE CONSTRUCTION							108 3										
MACHINE CONSTRUCTION LAB											74 1						
CHEMICAL MACHINERY															48 4		
CHEMICAL MACHINERY LAB																	
THERMODYNAMICS					90 6	MC CHEM ENG						60 5	@60 4	68 4	60 5	77 7	
HEAT ENGINEERING						33 3							@30 2			@44 4	
HEAT ENGINEERING LAB					90 2	33 3							@30* 2			@44 8	
POWER ENGINEERING		36 3	36				48 4	42 3	32 -			@84 7	60 4		72 6	@44 2	
POWER ENGINEERING LAB								24 1	64 3			96 4					
REFRIGERATION												36 3				33 3	
REFRIGERATION LAB																	
HEATING AND VENTILATING																	
HEATING AND VENTILATING LAB																	
GAS POWER													@30 2				
GAS POWER LAB													@45 1½				
FUELS AND OILS																	
FUELS AND OILS LAB																	
TESTING MATERIALS LAB				48 3			72 2					96 4	@45 1½		72 2		
ENGINEERING SEMINAR																	
CIVIL ENGINEERING																	
CIVIL ENGINEERING																	
CIVIL ENGINEERING FIELD																	
SURVEYING		36 3									24 2	36 3					18 ½
SURVEYING FIELD		72 2									24 1	72 2					90 1½
STRUCTURAL DESIGN							36 3									33 3	
STRUCTURAL DESIGN LAB																44 2	
ELECTRICAL ENGINEERING																	
ELECTRICAL ENGINEERING		36 3	72		60 4		72 6	102 6	32 -	48 6	50 2		60 4	102 6	24 2	66 6	
ELECTRICAL ENGINEERING LAB		48 2	108		120 2		108 3	102 2	64 3	40 2	24 1	48 2		102 3		77 3½	
ELECTRICAL MACHINERY			36			46 4						84 7	@45 3		96 8	33 3	
ELECTRICAL MACHINERY LAB						69 6							@105 4				
ILLUMINATING ENGINEERING																@22 2	
ELECTRIC POWER																	
ELECTRIC POWER LAB																	
POWER DISTRIBUTION																@44 4	
MINING ENGINEERING																	
GEOLOGY						69 6								51 3		22 2	
GEOLOGY LAB													@45 1½				
MINERALOGY							12 1	34 2						51 3	24 2		
MINERALOGY LAB							72 2	51 1					@354 1½		12 1		
MINING																	
PETROLEUM AND GAS																	
SANITARY ENGINEERING																	
SANITARY ENGINEERING																	
SANITARY ENGINEERING LAB																	
BACTERIOLOGY																	
BACTERIOLOGY LAB																	
BIOLOGY																	
BIOLOGY LAB																	

CHEMICAL ENGINEERING 1920-1921	GEO WASH UNIV	GEORGIA SCH TECH	HARVARD UNIV	IDAHO UNIV OF	IOWA STATE COL	IOWA STATE UNIV	KANSAS UNIV OF	LAFAYETTE COLLEGE	LEHIGH UNIV	LOUISIANA STATE UNIV CHEM ENG	LOUISIANA STATE UNIV SUGAR ENG	MAINE UNIV OF	MARQUETTE UNIV	MARYLAND UNIV OF	MASS INST TECH	MICHIGAN UNIV OF	MICHIGAN AGR COLL	MINN UNIV OF	MISSOURI UNIV OF	MONTANA SCH MINES	NEBRASKA UNIV
MECHANICS																					
THEORETICAL MECHANICS				160 10			90 5		16 1	72 2	72 2	54 3		108 9		64 4	120 10		128 8	72 6	
APPLIED MECHANICS	60 4	48			66 2			68 4					36 4		90 6	32 3					
APPLIED MECHANICS LAB					31½ 3			312 6					36 4			45					
STATICS					40 4							36 2									
DYNAMICS																					
KINEMATICS																					
HYDRAULICS				48 3		@270 5		34 2					45 5						48 3		
HYDRAULICS LAB								51 1			548 11⅓							46 2			
MECHANICS OF MATERIALS	60 4	32		MC APP MCH	60 5	216 8	72 4				@548 8⅓		111 12				60 5	48 4	32 2		
ELEMENTARY ENGINEERING							1 1														
ELEMENTARY ENGINEERING					MC CHEM MECH ENG				208 13				36 2								
ELEMENTARY ENGINEERING LAB		114																			
EXPERIMENTAL ENGINEERING					@32½ 3									72 6							
EXPERIMENTAL ENGINEERING LAB														108 3							
GENERAL ENGINEERING																					
GENERAL ENGINEERING LAB																					
MECHANICAL ENGINEERING																					
MECHANICAL DRAWING	180 4				1 1				144 9	360 5	360 5	216 4	130 7	108 3	120 4						
MECHANICAL DRAWING LAB		96	180	192 4	267 8	162 3	216 4	204 4									240 10	138 4	192 4	180 6	60 2
DESCRIPTIVE GEOMETRY		64		16 2			54 3						9 1	12 1	60 2	64 4	34 3	66 2		12 1	
DESCRIPTIVE GEOMETRY LAB		96		48 2		108 2		204 4					54 3	36 1		90	96 4		96 2	60 2	
GRAPHICS	90 2								96 6										64 2		
MECHANICAL ENGINEERING				16 1							24 7½						12 1				
MECHANICAL ENGINEERING LAB	180 4			64 1	66 2						@244 8½	54 1½	78 4	72 2			144 6				
SHOP WORK										360 5	360 5	64 2			90 3	32 4	60 3	210 6			60 3
SHOP WORK PRACTICE		192		32 2	365 6	216 4	216 4	105 2½								112	120 6		192 4	120 4	
MECHANISM	90 6			32 2						36 1	36 1		18 2		40 2					36 3	
MECHANISM LAB	60 2			96 2									54 3							30 1	
MACHINE DESIGN				144 3	MC CH ENG	@30* 2	18 1		144 9		@48 3	16⅔ 3	72 4		60 6	147 5	72 3	84 2	128 4		36 3
MACHINE CONSTRUCTION							54 1														
MACHINE CONSTRUCTION LAB											192 2½										
CHEMICAL MACHINERY																		44 4			
CHEMICAL MACHINERY LAB																		33 1			
THERMODYNAMICS	45 3	80		80 5	36 3					48 ⅓	72 2						48 4				69 6
HEAT ENGINEERING					31½ @3			68 4	64 4				35 4		80 4	80 4	36 3	66 6	32 2		
HEAT ENGINEERING LAB						@270 5		102 2	192 12			54 3	36 2		60 3			88 2	32 1	60 2	
POWER ENGINEERING	45 3	32			30 3						72 2						24 2				
POWER ENGINEERING LAB																					
REFRIGERATION					MC CH ENG																
REFRIGERATION LAB																					
HEATING AND VENTILATING																					
HEATING AND VENTILATING LAB																					
GAS POWER																					
GAS POWER LAB																					
FUELS AND OILS					MC IND CH													23 2		12 1	
FUELS AND OILS LAB													32 2					138 4		60 2	
TESTING MATERIALS LAB				96 2	MC M CH ENG		54 1						36 2		20 2			36 1	32 1		
ENGINEERING SEMINAR					MC CH SEM																
CIVIL ENGINEERING																					
CIVIL ENGINEERING																					
CIVIL ENGINEERING FIELD																					
SURVEYING													9 1			16 2			16 1		
SURVEYING FIELD								204 4½					66 5	72 2		45			96 2		
STRUCTURAL DESIGN					MC CH ENG																
STRUCTURAL DESIGN LAB													80 4								
ELECTRICAL ENGINEERING																					
ELECTRICAL ENGINEERING	60 4	45			65 6	@108 6		68 4	64 4	72 2	144 4	72 4	90 10		30 3	64 4	72 6				72 6
ELECTRICAL ENGINEERING LAB		45			129 4	@216 4		102 2	192 12	72 1	120 1⅔	54 1½	72 4		30 3	60	48 2				88½ 3
ELECTRICAL MACHINERY				64 4															64 4		
ELECTRICAL MACHINERY LAB				96 2															128 4		
ILLUMINATING ENGINEERING																					
ELECTRIC POWER																		@68 6		72 6	
ELECTRIC POWER LAB																		102 3		36 1	
POWER DISTRIBUTION																					
MINING ENGINEERING																					
GEOLOGY														36 3			24 2				
GEOLOGY LAB								340 8						1			24 1				
MINERALOGY	30 2			32 2	20⅔ 2		216 5		32 2					12 1							12 3
MINERALOGY LAB	60 2			96 2	61½ 2									36 1							60
MINING																					
PETROLEUM AND GAS																					
SANITARY ENGINEERING																					
SANITARY ENGINEERING																					
SANITARY ENGINEERING LAB																					
BACTERIOLOGY									16 1												
BACTERIOLOGY LAB									48 3												
BIOLOGY																					
BIOLOGY LAB																					



CHEMICAL ENGINEERING 1920-1921	ALABAMA POLY INST	ARKANSAS UNIV OF	ARMOUR INST TECH	BUCKNELL UNIV	CALIF. UNIV OF	CALIF INST TECH	CARNEGIE INST TECH	CASE SCH APP SCI	CATHOLIC UNIV AMER	CINCIN UNIV OF	CLEMSON AGR COLL	COLORADO UNIV OF	COLUMBIA UNIV	DELAWARE COLLEGE	DES MOINES COLLEGE	DETROIT UNIV OF	FLORIDA UNIV OF
	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT
148 SANITARY ENGINEERING CONT.											●						
149 SANITARY BIOLOGY																	
150 SANITARY BIOLOGY LAB																	
151 WATER AND SEWAGE													3 30 2	34 1			
152 WATER AND SEWAGE LAB																	
153 FILTRATION																	
154 SANITATION AND HYGIENE																	
155 CONSERVATION OF RESOURCES																	
SAFETY ENGINEERING																	
160 SAFETY ENGINEERING																	
161 SAFETY ENGINEERING LAB																	
162 ENGINEERING SEMINAR																	
INDUSTRIAL ENGINEERING																	
163 PRODUCTION ENGINEERING													3 30 2			3 22 2	
164 SCIENTIFIC MANAGEMENT							48 4					36 3	460 4			11 1	
165 ECONOMICS			72			57 5			192 6		37 1		90 6		60 3	253 3	36 1
166 ESTIMATES AND CONTRACTS												36 3					36 1
167 COMMERCIAL SPECIFICATIONS																	
168 COMMERCIAL LAW			36								74 2						
169 ACCOUNTING																	
170 FINANCE																	
171 ENGINEERING CONFERENCE																	
172 PUBLIC UTILITIES																	
173 HISTORY OF ENGINEERING																	
174 CO-ORDINATION										75 10						11 1	
175 INDUSTRIAL HYGIENE																	
176 INDUSTRIAL RELATIONS																22 2	36 1
ENGLISH																	
177 RHETORIC AND COMPOSITION		144 12	72	96 6		INC ENGING		51 3	96 3	20 3	75 3	108 9	90 6	102 6	96 8		108 3
178 ENGLISH LANGUAGE						170 15	144 10				37 1						
179 ENGLISH LITERATURE						136 12					39 3		45 3	68 4	36 3		
180 AMERICAN LITERATURE						INC ENGLISH					111 3						
181 SCIENTIFIC LITERATURE																	
182 LITERATURE IN GENERAL			36														
183 TECHNICAL WRITING						" "		51 3		45 6	37 1	24 2		34 2			36 1
184 ENGINEERING REPORTS								51 3				24 2					
185 PUBLIC SPEAKING				64 4		" "		51 3								311 1	
186 NEWSPAPER WORK																	
187 LIBRARY METHODS																	
LANGUAGES																	
188 FRENCH				96 6				884 12					105 7			55 5	
189 SPANISH																44 4	
190 ITALIAN																	
191 GERMAN				32 2	90 6	136 12	108 9						90 6			44 4	
192 LATIN																	
193 GREEK																	
194 CHOICE OF 2									96 3					204 12			
195 CHOICE OF 3																	
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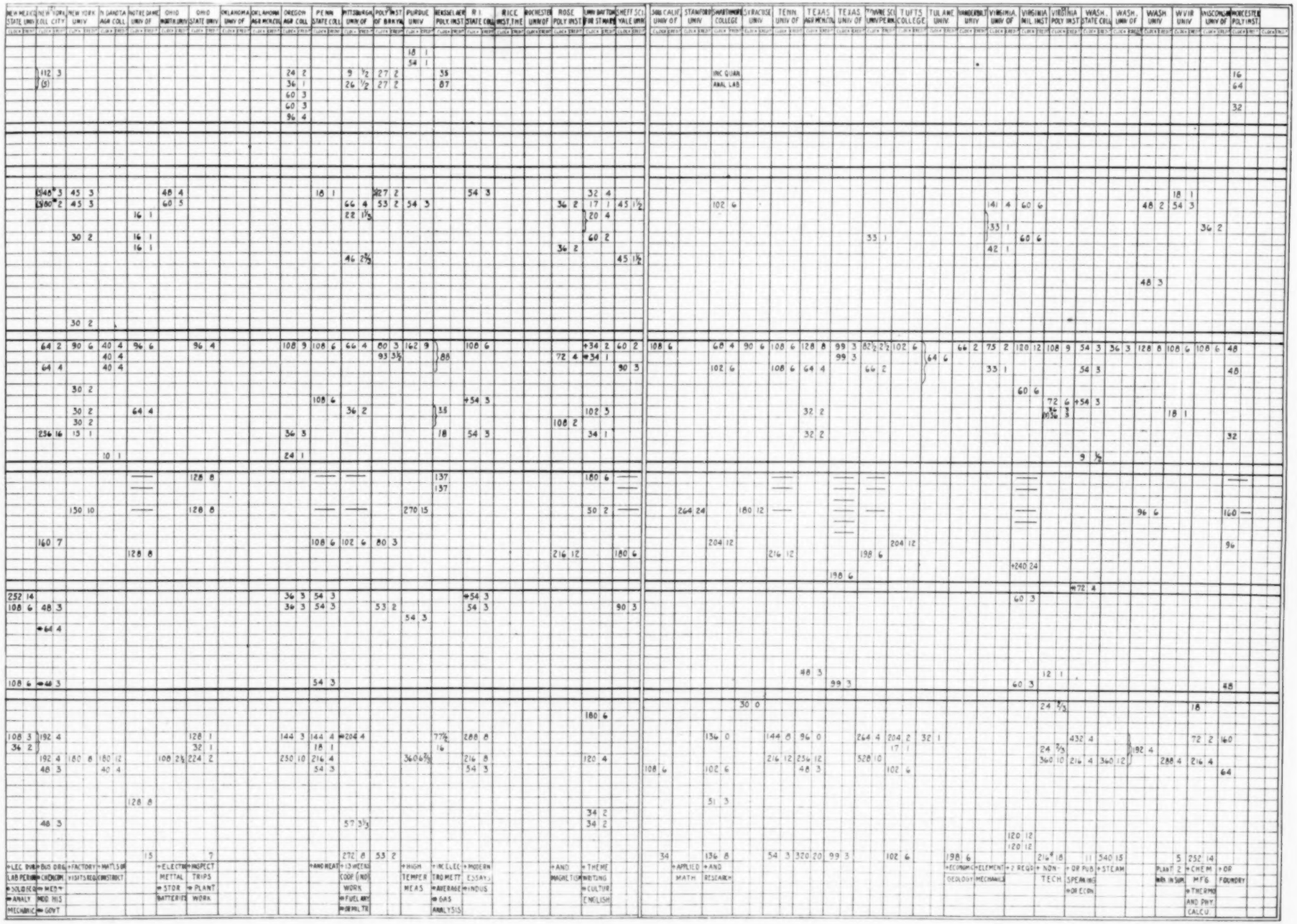
198 AMERICAN						INC ENGING					54 3			17 1			
199 EUROPEAN						" "					54 3						
200 NINETEENTH CENTURY			18														
201 CIVILIZATION			36										150 10				
202 SCIENTIFIC ATTAINMENTS																	
203 IRISH																	
204 CURRENT						INC ENGLISH											
205 CITIZENSHIP																	
206 POLITICAL SCIENCE			18				108 9										
MISCELLANEOUS																	
207 ORIENTATION						34 3									36 0		
208 MORAL TRAINING				15 1					128 4								
209 ENGINEERING ETHICS																	
210 PHYSICAL TRAINING			144	191 4	180 2	238 21	216 6	238 7			13 1		180 4		180 6		
211 HYGIENE					15 1						15 1		15 1				
212 MILITARY TRAINING		216 6			180 6	204 18				120 18	444 7			408 12			
213 POLITICAL ECONOMY							108 9	34 2								253 3	
214 POLITICS																	
215 SOCIOLOGY											37 1						
216 PHILOSOPHY													INCONCIN				
217 LOGIC			36														
218 PSYCHOLOGY			36														
219 ZOOLOGY											74 2						
220 ZOOLOGY LAB														102 6	20		54 1½
ELECTIVE		858 47		19	16												
REMARKS					●BASE BALL	●ASTRON	●DR MIL	●INCLUDES		●DESIGN	●ALGEBRA	●CHEMIST	●CHEMIS	●DELAWARE	●CHEM	●ECONOMY	
(5) AND (6) INDICATE Nº OF HOURS IN INSTITUTIONS HAVING 5TH & 6TH YEAR COURSES					●ANY ENG	ANAL LAB	TRAINING	GAS OILS		COURSE IS	AND GEOM	HEAT TREAT	STM PWR	HISTORY	PLANT DES	EMPIRICAL	
					●ANY GOOD	ENGINEERS		PETROLEUM		GIVEN ON	●INCLUDES	OF STEEL	●FACTORY	●NON TECH	●HYDRO-	EQUATIONS	
					●CALCULUS	●ENGLISH		●%		COOPERAT	FREE HAND	●INC P P	EQUIP ●256		MOTORS	LAB ●CLASS	
† REFERS TO NOTE IN FROM NAMED COLL					COMBINED	●ECON TOPICS				PLAN	STRU DRAW	EFFICIENCY	CONTEMPOR				

CHEMICAL ENGINEERING 1920-1921	GEO WASH UNIV	GEORGIA SCH TECH	HARVARD UNIV	IDAHO UNIV OF	IOWA STATE COLL	IOWA STATE UNIV	KANSAS UNIV OF	LAFAYETTE COLLEGE	LEHIGH UNIV	LOUISIANA CHEM ENG	STATE COL SUGAR ENG	MAINE UNIV OF	MASS INST TECH	MARYLAND UNIV OF	MASS INST TECH	MICHIGAN UNIV OF	MICHIGAN AGR COLL	MINN UNIV OF	MISSOURI UNIV OF	MONTANA COLL AGR	NEW HAMP COLL AGR
	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT	CLASS CREDIT
148 SANITARY ENGINEERING CONT.																					
149 SANITARY BIOLOGY								17 1													
150 SANITARY BIOLOGY LAB								85 2													
151 WATER AND SEWAGE					INC BIOCH														24 2		
152 WATER AND SEWAGE LAB					" "														60 2		
153 FILTRATION					" "													INC MECH			
154 SANITATION AND HYGIENE																					
155 CONSERVATION OF RESOURCES					24 2																
SAFETY ENGINEERING																					
160 SAFETY ENGINEERING																					
161 SAFETY ENGINEERING LAB																					
162 ENGINEERING SEMINAR																					
INDUSTRIAL ENGINEERING																					
163 PRODUCTION ENGINEERING					INC ENG CHE																
164 SCIENTIFIC MANAGEMENT					" "		54 3	51 3				36 2	372 8								
165 ECONOMICS						108 3	54 3		96 5				354 6				108 9		80 5	72 6	
166 ESTIMATES AND CONTRACTS					20 2												36 3				
167 COMMERCIAL SPECIFICATIONS					INC PUBLITY																
168 COMMERCIAL LAW	60 4							51 3							36 3						
169 ACCOUNTING																	24 2				
170 FINANCE																					
171 ENGINEERING CONFERENCE																					
172 PUBLIC UTILITIES					21 2																
173 HISTORY OF ENGINEERING																					
174 CO-ORDINATION													60 2								
175 INDUSTRIAL HYGIENE																	36 3				
176 INDUSTRIAL RELATIONS															60 6						
ENGLISH																					
177 RHETORIC AND COMPOSITION	90 6	96 3	90	64 4	36 3	108 6	144 8	102 6	32 2	108 3	108 3	72 4	27 3	108 9		64 4	72 6	105 9	96 6	144 12	108 9
178 ENGLISH LANGUAGE					30 3				32 2												
179 ENGLISH LITERATURE		96 3		96 6	31½ 3	108 6			32 2												
180 AMERICAN LITERATURE		48 3			24 2				16 1												
181 SCIENTIFIC LITERATURE												18 1									
182 LITERATURE IN GENERAL									16 1												
183 TECHNICAL WRITING		32 1							16 1			36 2		72 6		32 2			32 2	48 4	
184 ENGINEERING REPORTS					INC ENG LAB		40 2											INC MECH		24 2	
185 PUBLIC SPEAKING					21 2				16 1			72 4	27 3	36 3			60 5			36 3	
186 NEWSPAPER WORK																					
187 LIBRARY METHODS																		INC CHEM			
LANGUAGES																					
188 FRENCH			90			144 8															
189 SPANISH																					
190 ITALIAN																					
191 GERMAN			90			144 8	180 10		112 7			56 2			120 6			210 18			108 3
192 LATIN																					
193 GREEK				144 9																	
194 CHOICE OF 2									48 3			180 10		216 18							108 9
195 CHOICE OF 3	90 6	192 6														256 16					
196 CHOICE OF 4																					
197 CHOICE OF 5																					
HISTORY																					
198 AMERICAN																					
199 EUROPEAN																	60 5				
200 NINETEENTH CENTURY														108 9							
201 CIVILIZATION																					
202 SCIENTIFIC ATTAINMENTS					INC SEMING																
203 IRISH																					
204 CURRENT																					
205 CITIZENSHIP																			64 4		
206 POLITICAL SCIENCE																					
MISCELLANEOUS																					
207 ORIENTATION		12 1																105 3		12 1	
208 MORAL TRAINING								136 8													
209 ENGINEERING ETHICS													208 2								
210 PHYSICAL TRAINING			90		65 6	72 4		204 4	224 14			3 2½			30 1		288 0		128 4		72 1½
211 HYGIENE			30†																		
212 MILITARY TRAINING		320 10		288 4	65 6	216			96 6	4	4	12 4		216 6	180 6		216 0		192 4	72 6	216 9
213 POLITICAL ECONOMY		48 3												108 9	90 3						
214 POLITICS																					
215 SOCIOLOGY																					
216 PHILOSOPHY																					
217 LOGIC																					
218 PSYCHOLOGY																					
219 ZOOLOGY																					
220 ZOOLOGY LAB																					
ELECTIVE	90 6		●BIB LYS				108 3		32 2	13	7		372 8	12	60 3	192 12	4	(6) 11	(6) 11	2	216 18
REMARKS	●GRAD AND		●UNRESTR	●COMPULS	●INC DESIGN	●PLANT	●INDUS	●BIBLE	●SUMMER		WHEN SPEND	●HELP TRIPS	●26 WEEKS	●INCLUD	●CALAMITIES		●PYRO-	●CHEM MFG	●INC CLASS	●SUPP BY	●GAS
(5) AND (6) INDICATE Nº OF HOURS IN INSTITUTIONS HAVING 5TH & 6TH YEAR COURSES	RESEARCH		●RESTRICT	●INC COMP	●ENG PROB	INSPECT	ADMINS		READING		8-10 WEEKS	PULP AND	●ALSO IN	QUAL ANAL	●CALORIFIC		METRY	●CHEM ENG	DISCUSSION	PLANT	ANALYSIS
	WORK IN		TECHNIQUE		●THERMO	●CHEM			IN ECON		IN FACTORY	PAPER SEC			●INCREASE			●CAL AND	●ALGEBRA	INSPECT	
	DYES AND		MATH OR		MACHINERY	APPAR					WORK DURING	ELECTROLYTIC	LABORATORY		●EMPHASIS			APP MECH	AND TRIG		
	EXPLOSIVES		ENGLISH		●VALUAT	DESIGN					SUGAR SCA	BLEACH	REPORTS		●NON TECH			●INC ELEC			
† REFERS TO NOTE IN FROM NAMED COLL																					


NEW MEXICO STATE UNIV
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TULANE UNIV
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WISCONSIN UNIV OF
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Specifications for the Color of Gypsum Plasters

By Warren E. Emley and Charlotte G. Faxon*

In THE Tentative Specification for Gypsum Plasters, published by the American Society for Testing Materials, in 1920, the following paragraph occurs:

"Calcined gypsum for finishing coat may or may not contain retarder. It may be sold in two grades—viz., 'white' and 'gray.'"

Numerous cases are on record where dealers have ordered gypsum plaster of such a color that it will match a previous shipment. If the second lot is to be used to patch a wall which has been plastered with the first lot, obviously the colors must match pretty closely.

For white coat work it is customary to mix calcined gypsum with lime putty. Unless the mixing is done with unusual care, there will be spots of lime visible in the finished wall. Just how plainly visible these spots are will depend upon the relative colors of the lime and the gypsum. If they are both the same color, the spots will be invisible; if one is nearly white and the other dark, the effect may be be so bad as to condemn the plaster.

Investigations for Measuring the Color of Gypsum Plasters

The above citations illustrate the need for some method of measuring the color of gypsum plasters and of specifying any color which may be desired. In order to meet this need an investigation was undertaken at the Bureau of Standards, and this paper is intended to present the results so far obtained.

Fortunately, the method had already been established, and the equipment was available. These are described in detail in Bureau of Standards Technologic Papers 92 and 167. Irwin G. Priest, chief of the color section of the bureau and senior author of both of the above papers, has co-operated with us not only by giving personal supervision to the experimental work, but also by assisting in the interpretation of the data.

A careful study of the subject can be made only by reference to the two papers cited above. For this reason, only a brief description of the method used will be given here.

A small block of the plaster to be examined was molded and allowed to become thoroughly dry and hard. It was mounted for spectrophotometric examination beside a standard block of magnesium carbonate in a box so that the sample and standard were diffusely and equally illuminated, and so placed that one half of the spectrophotometer field was illuminated by light reflected by the sample, while the other half was illuminated by light reflected by the standard. By rotating a Nicol prism, the brightness of one half the field may be made to increase, while that of the other half simultaneously decreases. When the two halves match, the position of the prism indicates the relative quantities of light reflected from the sample and the standard. By rotating a glass prism in the path of the reflected light any desired wave-length may be selected, light of every other wave-length being simultaneously cut off. It is thus possible to measure the ability of the sample to reflect light of any wave-length and to compare this ability with that of the standard magnesium carbonate which reflects nearly 100 per cent of the light falling on it. The ratio between the intensities of the light of any given wave-length reflected by the sample and by the standard may be expressed as a percentage, and may be plotted against the wave-length. This method of expressing the results is shown in Fig. 1, which is drawn from actual data obtained by measurements of the reflecting powers of a gypsum plaster for lights of different wave-lengths.

A careful study of this curve is worth while, as it illustrates several points pertinent to the problem in hand. If the curve is a straight, horizontal line, the color which it represents will be neutral—white, gray, or black. Whether the color is white or black will be indicated by the position of the line. If the line shows 100 per cent reflection for all wave-lengths, the sample is as nearly white as the standard. A perfect black would show zero per cent reflection for all wave-lengths; intermediate positions of the line indicate varying shades of gray, but the grays are purely neutral only when the line is straight and horizontal. In the case illustrated, the line is neither straight nor horizontal. It shows that the reflecting power of the sample for blue light was deficient, which is another way of saying that the sample has a yellow or red tint, and the sample varies from neutral gray to that extent. Since the reflecting power runs from about 50 per cent of that of the standard in the blue to about 70 per cent in the red, it is evident that the neutral gray to which the color of this sample approaches is not very nearly white.

Fig. 2 shows the approximate average spectral distribution of light from the noon sun at Washington. If the ordinate of this curve corresponding to each wave-length is multiplied by the per cent reflection for that wave-length as shown in Fig. 1, the results may be plotted to give the curve in Fig. 3. This curve represents the spectral distribution of sunlight after reflection from the sample. The area under this curve is proportional to the total reflection of the sample for sunlight. This area may be expressed as a fraction of the area under the standard curve, Fig. 2. The relative brilliance of the sample is then directly proportional to the logarithm of this fraction.

Measurements were made on thirteen samples of gypsum plasters, to determine their ability to reflect lights of different wave-lengths. The results were plotted in curve form, of which Fig. 1 is typical. All of the curves were of the same general shape—that is, all of the plasters had a yellow or red tint. The curves differed in their positions, however, which shows that some of the samples approached the whiteness of the standard more closely than others did.

Requirements for Specifying the Color of a Plaster

Inasmuch as the samples examined were selected as being representative of the entire field and the curves were all found to be similar in shape and without pronounced breaks, it may be assumed that gypsum plasters will not show any pronounced color unless some pigment has been intentionally added. The color of a plaster may therefore be specified by stating how much it varies from gray (that is, how red or yellow it is), and how far this gray departs from the standard white. The former requirement may be expressed numerically as the ratio of the per cent reflection of blue light (compared with the standard) to the per cent reflection of

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*Bureau of Standards, Washington, D. C.

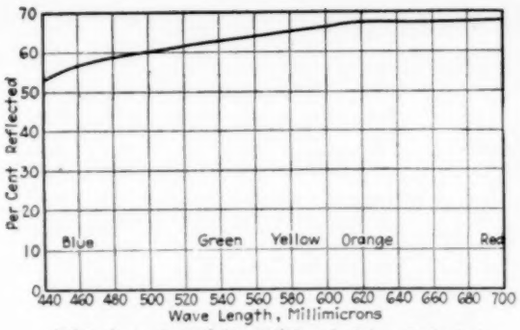


FIG. 1 – Amount of Light of Different Colors Reflected by Sample No. 9 Expressed as Per Cent of the Amount Reflected by a Standard White Surface.

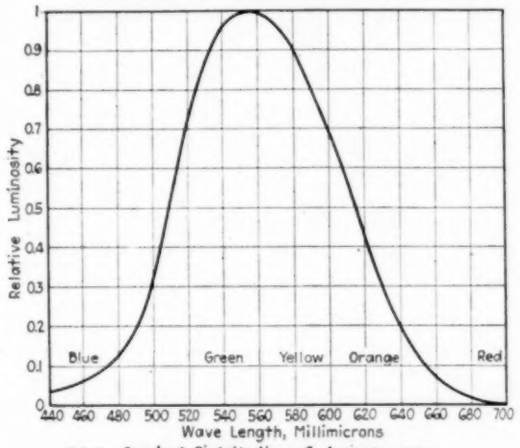


FIG. 2 – Spectral Distribution of Average noon Sunlight at Washington D.C.

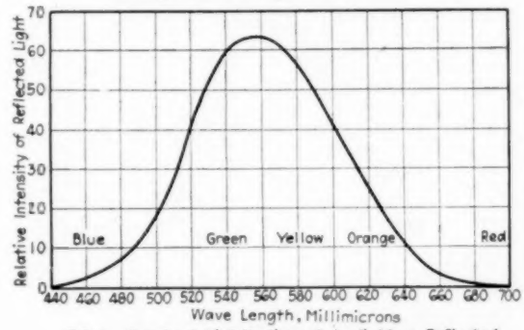


FIG. 3 – Spectral Distribution of Sunlight as Reflected from Sample No. 9. Each Ordinate is the Product of the Correspondent Ordinates of Figs 1 and 2

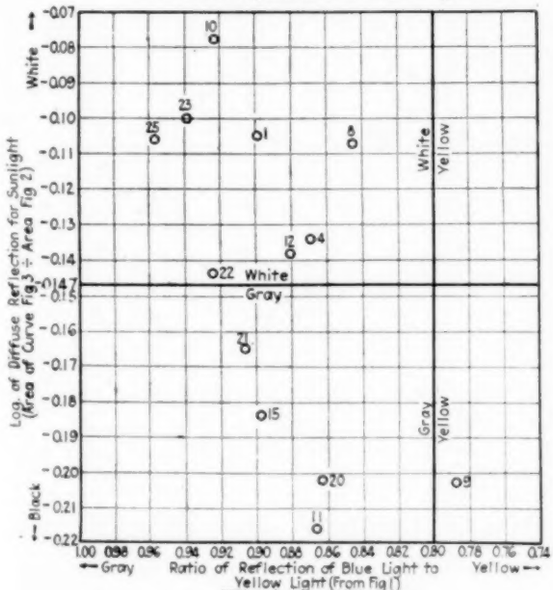


FIG. 4 – Comparative Colors of Samples Examined

yellow light. Blue light has a wave-length of 436 millimicrons; yellow light, 578 millimicrons. If this ratio is 1, the sample is gray; if greater than 1, it has a blue tint; if less than 1, a yellow tint. The second requirement has already been defined as being numerically expressed by the logarithm of the ratio between the area of the curve shown in Fig. 3 to the area of the sunlight curve shown in Fig. 2.

The results obtained from the thirteen samples examined are listed in the following table, and are shown in the form of a diagram in Fig. 4.

Sample No.	Description of Sample	Ratio of Reflection Blue:Yellow	Log. of Ratio Total Reflection of Sample : Total Reflection of Standard
1.	Plaster of paris F (Nova Scotia gypsum)	0.900	0.105
4.	Windsor FFF plaster (Nova Scotia gypsum)	0.870	0.134
8.	Superfine Windsor cement (Nova Scotia gypsum)	0.846	0.107
9.	Wood fibered plaster (Nova Scotia gypsum)	0.787	0.203
10.	Potters' plaster (Nova Scotia gypsum)	0.923	0.078
11.	Retarded gaging plaster, Oklahoma	0.866	0.216
12.	Unfibered cement plaster, Oklahoma	0.881	0.138
15.	Molding plaster, Oklahoma	0.898	0.184
20.	Molding plaster, Ohio	0.863	0.202
21.	Stucco, Iowa	0.907	0.165
22.	Retarded stucco, Iowa	0.925	0.144
23.	Molding plaster, New York	0.939	0.100
25.	Stucco, New York	0.957	0.106

In the last column a small number indicates a close approach to the whiteness of the standard. The smaller the number in the next to the last column the more yellow is the sample. If this figure were 1, the sample would be gray.

In Fig. 4 a horizontal line has been drawn midway between the extreme values of samples 10 and 11. It is proposed that all samples falling above this line may be called white, and all samples falling below it gray. A careful visual examination of the samples indicates that this classification is satisfactory.

The position of the vertical line has been arbitrarily fixed. Sample 9 is apparently the only one which might be condemned as being too yellow, and the line has been placed accordingly. Samples falling to the right of this line should not be designated as either white or gray; they are yellow.

The requirements suggested for a "white" plaster are therefore: (1) The logarithm of the diffused reflection for average sunlight shall be numerically less than 0.147, and (2) the ratio of the reflection of blue light (wave-length = 436 millimicrons) to the reflection for yellow light (wave-length = 578 millimicrons) shall be not less than 0.8.

For a "gray" plaster, requirement 1 as changed to read "more than" instead of "less than." Requirement 2 is the same for both white and gray plasters.

While it is believed that a "white" plaster meeting the requirements given above will be nearly enough white to be satisfactory for all commercial purposes, it must be remembered that the requirements are rather lenient. Therefore, white plasters may differ noticeably among themselves. If it is necessary that two white plasters shall match each other, much more rigid requirements must be specified.

In case a plaster of perfectly definite color is desired, an individual specification must be written, for it is obvious that there can be as many such specifications as there are colors. It is suggested that in writing such a specification a curve similar to Fig. 1 be drawn, indicating the desired color by the shape and position of the curve. A deviation from the curve of 5 per cent either way at any wave-length should be permitted.

Byproduct Coke Plants in the United States

The following list of manufacturers of byproduct coke in the United States May 1, 1921, has been compiled by the United States Geological Survey:

Operator	Address	Name or Location of Works	Number and Kind of Ovens
Alabama			
Alabama By-Products Corp.	American Trust Bldg., Birmingham.	Birmingham	50 Koppers
Gulf States Steel Co.	Brown-Marx Bldg., Birmingham	Alabama City	37 Koppers
Semet-Solvay Co.	Syracuse, N. Y.		
Also in Ill., Ky., Mich., N. Y., Ohio, Pa., W. Va.			
(Tenn. C. I. & R.R. Co.)	(Birmingham)	Ensley	240 Semet-Solvay
(Central Iron & Coal Co.)	(Holt)	Tuscaloosa	60 Semet-Solvay
Sloss-Sheffield Steel & Iron Co.	American Trust Bldg., Birmingham	Birmingham	120 Semet-Solvay
Tennessee Coal, Iron & R.R. Co.	Birmingham	Fairfield	434 Koppers
Woodward Iron Co.	Woodward	Woodward	80 Koppers
			60 Wilputte
			90 Koppers being rebuilt
Colorado			
Colorado Fuel & Iron Co.	Boston Bldg., Denver	Minnequa	120 Koppers
Illinois			
Chicago By-Product Coke Co.	Peoples Gas Bldg., Chicago	Chicago	100 Koppers building
Coal Products Mfg. Co.	Aurora	Joliet	35 Koppers 18 Wilputte
Illinois Steel Co. (Also in Ind.)	208 South La Salle St., Chicago	Joliet	280 Koppers
International Harvester Co.	606 South Michigan Ave., Chicago	South Chicago	88 Wilputte
North Shore Gas Co.	Waukegan	Waukegan	13 Semet-Solvay
St. Louis Coke & Chemical Co.	208 South La Salle St., Chicago	Granite City	80 Roberts 240 Roberts building
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse, N. Y.		
(By-Products Coke Corp.)	(Chicago)	South Chicago	280 Semet-Solvay
Indiana			
Central Indiana Gas Co.	Muncie	Muncie	22 Klonne
Citizens Gas Co.	Majestic Bldg., Indianapolis	Langsdale	41 Semet-Solvay
		Prospect	100 United-Otto 40 Wilputte
Illinois Steel Co. (Also in Ill.)	208 South La Salle St., Chicago, Ill.	Gary	700 Koppers
Indiana Coke & Gas Co.	Terre Haute	Terre Haute	30 Gas Machinery 30 Koppers
Inland Steel Co.	South Dearborn St., Chicago, Ill.	Indiana Harbor	130 Koppers
Linton Gas Co.	Linton	Linton	3 Gas Machinery
Steel & Tube Co. of American (Also in Wis.)	111 W. Washington St., Chicago, Ill.	Indiana Harbor	120 Semet-Solvay
Kentucky			
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse, N. Y.		
(Kentucky Solvay Coke Co.)	(Ashland)	Ashland	108 Semet-Solvay
Maryland			
Bethlehem Steel Co. (Also in Pa.)	Bethlehem, Pa.	Sparrows Point	300 Koppers
Massachusetts			
New England Fuel & Trans. Co.	111 Devonshire St., Boston	Everett	400 United-Otto
Michigan			
Ford Motor Co.	Dearborn	Dearborn	120 Semet-Solvay
Michigan Alkali Co.	Wyandotte	Wyandotte	54 United-Otto
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse, N. Y.	Detroit	215 Semet-Solvay
Minnesota			
Minnesota By-Product Coke Co.	1000 Hamline Ave., St. Paul	St. Paul	65 Koppers
Minnesota Steel Co.	Morgan Park Station, Duluth	Duluth	90 Koppers
Zenith Furnace Co.	West Duluth	West Duluth	65 United-Otto
Missouri			
Laclede Gas Light Co.	1017 Olive St., St. Louis	St. Louis	56 Koppers
New Jersey			8 Piette building
Camden Coke Co.	80 Park Place, Newark	Camden	150 United-Otto
Seaboard By-Product Coke Co.	Box 267, Jersey City	Kearny	165 Koppers
New York			
Donner-Union Coke Corp.	Box 193, Buffalo	Buffalo	150 Koppers
Empire Coke Co.	Geneva	Geneva	46 Semet-Solvay
Lackawanna Steel Co.	Buffalo	Lackawanna	94 United-Otto 282 Rothberg 60 Semet-Solvay
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse	Solvay	40 Semet-Solvay
(Wickwire Steel Co.)	(Buffalo)	Buffalo	60 Semet-Solvay
Ohio			
American Steel & Wire Co.	Western Reserve Bldg., Cleveland	Cleveland	180 Koppers
Brier Hill Steel Co.	Youngstown	Youngstown	84 Koppers
Hamilton-Otto Coke Co.	Hamilton	Kokotto	100 United-Otto
McKinney Steel Co.	Perry-Payne Bldg., Cleveland	River Furnaces	204 Koppers
National Tube Co.	Frick Bldg., Pittsburgh, Pa.	Lorain	208 Koppers
Penn Iron & Coal Co.	Leader-News Bldg., Cleveland	Canal Dover	24 Roberts
Republic Iron & Steel Co.	Republic Bldg., Youngstown	Youngstown	143 Koppers
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse, N. Y.		
(Otis Steel Co.)	(Cleveland)	Cleveland	100 Semet-Solvay
(Ironton Solvay Coke Co.)	(Ironton)	Ironton	60 Semet-Solvay
(Portsmouth-Solvay Coke Co.)	(Portsmouth)	Portsmouth	108 Semet-Solvay
Toledo Furnace Co.	Western Reserve Bldg., Cleveland	Toledo	94 Koppers
United Furnace Co.	Western Reserve Bldg., Cleveland	Canton	47 Koppers
The Youngstown Sheet & Tube Co.	Stambaugh Bldg., Youngstown	Youngstown	306 Koppers
Pennsylvania			
Allegheny By-Product Coke Co.	McKeesport	Glassport	120 United-Otto
Bethlehem Steel Co. (Also in Md.)	Bethlehem	Bethlehem	424 Koppers
		Lebanon	90 Semet-Solvay
		Steelton	120 Semet-Solvay 60 Koppers
Cambria Steel Co.	Widener Bldg., Philadelphia	Franklin	210 United-Otto 92 Koppers 190 Cambria-Belgian 60 Camb.-Belg. bldg.
		Rosedale	60 Cambria-Belgian 88 Semet-Solvay bldg.
Carnegie Steel Co.	Carnegie Bldg., Pittsburgh	Clairton	768 Koppers
		Farrell	212 United-Otto
Jones & Laughlin Steel Co.	Pittsburgh	Pittsburgh	300 Koppers
Philadelphia Suburban Gas & Electric Co.	Chester	Chester	40 Semet-Solvay
Pittsburgh Crucible Steel Co.	Pittsburgh	Midland	100 Koppers
Rainey-Wood Coke Co.	52 Vanderbilt Ave., N. Y. City	Swedeland	110 Koppers
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse, N. Y.		
(American Manganese Mfg. Co.)	(Philadelphia)	Dunbar	110 Semet-Solvay
Rhode Island			
Providence Gas Co.	Turks Head Bldg., Providence	Sassafras Point	40 Koppers
Tennessee			
Chattanooga Coke & Gas Co.	James Bldg., Chattanooga	Alton Park	24 Semet-Solvay
Washington			
Seattle Lighting Co.	Stuart Bldg., Seattle	Seattle	20 Klonne
West Virginia			
Domestic Coke Corp.	Drawer 436, Cleveland, O.	Fairmont	60 Koppers
La Belle Iron Works	Steubenville, O.	Follansbee	94 Koppers
Semet-Solvay Co. (Also in Ala., etc.)	Syracuse, N. Y.		
(National Tube Co.)	(Pittsburgh, Pa.)	Benwood	120 Semet-Solvay
Wisconsin			
Milwaukee Coke & Gas Co.	Milwaukee	Milwaukee	120 Semet-Solvay
Steel & Tube Co. of America	First Nat'l Bank Bldg., Milwaukee	Mayville	108 United-Otto

The Slip Interference Theory of the Hardening of Metals

A Mechanical Conception of Hardening of Pure Metals, Allotropic and Non-Allotropic, of Solid Solutions of Constant or Variable Solubility, and of Metallic Aggregates—In General, Hardness Is Due to Interference With Slip, a Characteristic Property of Ductile Crystals

By ZAY JEFFRIES and R. S. ARCHER

IN GENERAL, pure metals in their normal condition are relatively soft and weak. They can be usefully hardened and strengthened by mechanical work and by alloying, and their alloys can often be further hardened by heat-treatment. The methods of hardening the different metals vary so much in detail, and the phenomena which accompany hardening are so unique, that there has arisen a variety of special theories to account for the mechanism of hardening. It is our purpose to present a more general theory applicable to all cases.

Definition of Hardness and Absolute Cohesion

The general terms "hardness" and "strength" connote a number of more specific physical properties. The most definite of these is the proportional limit or, what is practically the same thing, the elastic limit. The common measure of the strength of a material is its "tensile strength," or the maximum intensity of tensile stress endured before rupture, calculated on the original cross-sectional area of the test-piece. This is obviously a more complex property than the elastic limit. Hardness may mean resistance to indentation, as measured by the Brinell test; resilience, as measured by the Shore scleroscope; scratch hardness, cutting hardness, resistance to machining, or some other special kind of hardness. All of these properties may be embraced in the general definition: *Hardness is resistance to permanent deformation.*

Metals owe their hardness and strength to the attractive forces between their atoms. Any permanent deformation of a metal involves changes in the relative positions of some of the atoms, and therefore the breaking, temporarily at least, of some interatomic "bonds." The rupture of any material, whether with or without permanent deformation, also involves the breaking of interatomic bonds. The greatest possible resistance that a material can offer to deformation or rupture is the summation of all the interatomic bonds on a plane through the specimen normal to the stress, a summation which may for convenience be termed the "absolute cohesion" of the material. Actually such a summation of forces never is realized, and its total is more than sufficient to account for the strength of the strongest alloys. Rupture always takes place by degrees, and the breaking of atomic bonds is not simultaneous. The tensile strength of a material therefore represents the maximum number of atomic bonds that come into play simultaneously during the test, and since the elastic limit usually comes at a lower stress, it represents a still smaller percentage of the absolute cohesion.

Absolute cohesions of metals are far in excess of the values obtained for tensile strength. A qualitative illustration of this fact may be found in a consideration of some properties of pure iron. The tensile strength, in the hot-rolled condition, is about 40,000 lb. per sq.in., a value representing as usual the maximum load divided by original cross-section. If the actual reduced area of the test-piece is measured throughout the progress of the test and the stress computed on this basis, a value will be found for the maximum stress which is much higher than the tensile strength. The maximum stress will then be about 80,000 lb. per sq.in. Severely cold-worked iron may show a tensile strength of 150,000 lb. per sq.in. The maximum actual stress is again somewhat higher (165,000), but not in so large a ratio as in the case of the hot-rolled iron.

Even in the cold-worked iron, rupture still takes place by degrees—that is, by a kind of tearing action—so that the highest of these figures still does not represent the inherent absolute cohension. The significant thing is that the inherent cohesion of the pure metals is more than sufficient to account for the strength of their strongest alloys. The strengthening of a metal by cold-work can only be due to some mechanism by which the interatomic bonds are brought more effectively into play, so that more of them have to be broken simultaneously. When a metal is strengthened by alloying, the interatomic forces due to the presence of unlike atoms may enter as an additional factor, but the main factor in the hardening and strengthening consists in taking better advantage of the great inherent cohesion of the principal metal.

Metals are crystalline and are built up of atoms arranged in definite and repeating patterns. The regularity of atomic arrangement gives rise to certain planes of weakness, or low resistance to shearing stress. When an external load produces a shearing stress on such a plane which exceeds the resistance of the crystal to shear on that particular plane, fracture of the crystal takes place. The fragments formed may or may not adhere to each other. If they do not, the failure of the crystal is complete, and it is said to be brittle. The plane of weakness is then known as a cleavage plane. More generally, in the useful metals, the crystal fragments adhere and merely glide or "slip" over each other. The result of such slip, repeated on many planes, is a measurable permanent deformation; the crystal is ductile, and the planes of weakness are called "slip planes."

The first appreciable formation of slip planes marks the beginning of plastic deformation and therefore the passing of the elastic limit. The resistance to permanent deformation, which is a general measure of hardness and strength, represents resistance to the beginning and propagation of slip. Anything that serves to hinder slip is a source of strength and hardness. *The hardening and strengthening of metals by any of the known methods may be considered as due principally to interference with slip.*

Fracture in a Single Ductile Crystal

Fig. 1-A represents a test-bar of square cross-section, which is supposed to consist entirely of a single grain of a ductile metal. It is further supposed that this grain has such an orientation that planes of easy slip are perpendicular to the plane of the paper and make angles of about 45 deg. with the axis of the test-piece. Now if the piece is subjected to tension, shearing stresses are developed which reach a maximum value at 45 deg. to the tensile load and hence parallel to the planes of easy slip. As these stresses increase, failure of the crystal will take place in the form of slip, or block movement, along one of these

planes, *ab*, the location of which will generally be determined by some local weakness. (Fig. 1-B.)

Ductile metals possess the property of automatically limiting the extent of the movement on any particular slip plane. Instead of slip continuing on the first plane until complete rupture of the piece occurs, the movement comes to a stop after a displacement which is very small as compared with the dimensions of the test-piece. The actual displacement may be something on the order of one twenty-thousandth of an inch, or about 5,000 atom diameters. The resistance to movement along the first slip plane increases so that slip is forced to take place on new planes.

The amorphous metal theory of Beilby offers what appears to the present authors to be the only completely satisfactory explanation of this phenomenon. The rubbing together of the crystal fragments on the plane of slip is supposed to tear some of the surface atoms loose from their regular crystalline arrangement, thus forming a layer of amorphous metal. The friction generates heat rapidly so that a high

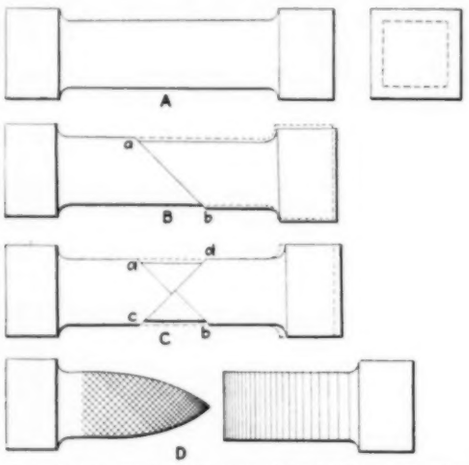


FIG. 1. A TO D. PLASTIC DEFORMATION OF TEST-BAR COMPOSED OF A SINGLE DUCTILE CRYSTAL

temperature is reached locally. This high local temperature softens the amorphous metal, which is essentially merely an undercooled liquid. With the softening of the amorphous metal layer the resistance to slip diminishes and there is less frictional heat developed. The high local temperature is then quickly dissipated by conduction to the surrounding metal, whereupon the amorphous metal hardens and offers a resistance to further slip which is greater than that on planes on which slip has not yet occurred.

To return to our single crystal test-bar, let us suppose that the second slip is on a conjugate plane *cd*, making an angle of about 90 deg. with the planes of the first set. (Fig. 1-C.) It is readily seen how repeated slips of this character result in a general increase in the length of the test-bar, and a decrease in its diameter.

Fig. 1-D represents the test-bar after rupture. The view on the left shows the same surface of the bar as in the three views above, and illustrates the multiplication of intersecting slip planes, especially near the fracture. The view on the right shows a face of the test-bar at 90 deg. to that on the left. It will be noted that there has been no reduction in diameter on this face at the fracture. The test-piece has drawn out into the shape of a wedge. This result has actually been obtained by Sykes[1] on single-crystal wires of molybdenum, and similar results have been obtained by the authors with aluminum.

Relation Between Grain Size and Strength

In the single-crystal test-piece with its planes of easy slip parallel to the maximum shearing stress we have the worst possible condition for resisting an applied load. The resistance to the beginning of slip is limited to the shearing strength of the crystal, since the exterior surfaces of the crystal are free and are not supported in any way. After slip has occurred on a number of planes additional resistance to slip is created, as will be explained later, and the maximum load sustained may be well above the load required to produce the first slip.

Ordinary pieces of metal are aggregates of many crystalline grains of different orientations. Between the grains there must exist metal of disordered atomic arrangement. Whether or not this boundary metal possesses the perfectly random arrangement of atoms demanded for the "vitreous amorphous" cement of Beilby, it appears to possess the fluid characteristics of amorphous substances. At low temperatures it furthermore possesses great hardness and strength, doubtless because of the absence of potential slip planes.

In an aggregate of many grains of different orientation, there cannot be any continuous plane of weakness. The application of a load cannot produce any slip planes extending entirely across the section, as in the case of the single grain just considered. When slip takes place in any one grain it cannot continue without change of direction into adjacent grains because, except in very rare instances, the potential slip planes of adjacent grains do not register. The permanent deformation of the metal is thus resisted at the grain boundaries by the disregistry of the planes of low cohesion, and especially in fine-grained metals, by the specific hardness of the amorphous cement, which itself is due to the absence of planes of weakness. The result is an increase in elastic limit, hardness, and strength.

Sykes' tests on molybdenum wire are of particular interest in this connection, since we have single-grain wire as a starting point. The following figures are a striking illustration of the strengthening effect of grain refinement:

Grain Size	Tensile Strength Lb. per Sq.In.
Single grain[2]	32,000
Average grain diameter of 0.0011 in.	51,000
Average grain diameter of 0.0002 in.	96,000

All these wires had a diameter of 0.025 in., and were tested at 300 deg. C., far below the lowest annealing temperature of molybdenum, which is about 900 deg. C. At this temperature (300) the results are properly comparable, since all specimens possessed considerable ductility.

The effect of grain size on the hardness of alpha brass has been carefully worked out by Bassett and Davis[3]. Fig. 2 shows their results obtained on a 68-32 brass. The specimens having a Brinell hardness of 80 or less are stated to be completely recrystallized. A change in hardness from 42 to 80 is therefore attributable entirely to grain refinement. From these results and his own observations, Prof. C. H. Mathewson of Yale has deduced an equation connecting hardness and grain size, as follows:

$$\textit{Brinell Hardness} = \frac{K}{\sqrt[4]{D}}$$

where D is the diameter of average grain in millimeters, and the constant K has a value of about 30.

It is evident that twinning planes as well as grain boundaries represent discontinuity of the planes of weakness and hence interference with slip. The change in orientation at a twinning plane, however, is much less complete than at a grain boundary, and the strengthening effect is therefore less. While it is not possible for slip to take place through twin crystals on a continuous *plane*, it is possible and probably usual for slip to follow a continuous *surface*, which has the form of a "broken plane." The intersection of such a surface with the plane of a polished specimen is a broken line. Slip bands through twins are accordingly continuous but change direction at each twinning plane. (See Figs. 9 and 10, page 1063.)

[1] "Effect of Temperature, Deformation, Grain Size and Rate of Loading on the Mechanical Properties of Metals," W. P. Sykes, A.I.M.E., February, 1921, meeting.

A.I.M.E., vol. 60, p. 428.

[2] The molybdenum wire tested by Sykes was made up of large grains which occupied the entire cross-section of the wire, but did not extend the full length of the pieces tested. Since each test-piece contained several grains of varying orientation, failure would be most apt to occur in that grain which happened to have planes of easy slip most nearly in the direction of maximum shear stress. Furthermore, it is probable that out of the number of grains involved some one grain was oriented very nearly in this direction of greatest weakness. The results therefore represent the lowest strength of molybdenum of the size tested. If the elastic limit had been determined we would have a value very close to the resistance to shear on the planes of easiest slip.

[3] "A Comparison of Grain Size Measurements and Brinell Hardness of Cartridge Brass," W. H. Bassett and C. H. Davis, *Trans.*

The permanent deformation of a metal by cold-work involves the breaking of the grains into fragments along intersecting systems of slip planes, and movement of these fragments with respect to each other. In the first stages of deformation the crystalline fragments within any one grain undoubtedly retain considerable uniformity of orientation. As the deformation proceeds, there must be some rotational movement of the fragments, this being especially true near the old grain boundaries. In so far as new orientations are created, the effect is equivalent to grain refinement. It is probable that even after severe cold-working there is still general uniformity of orientation in the fragments of any particular grain. The slip interference at the surfaces between such fragments of somewhat similar orientation is therefore more on the order of the interference at twinning planes than of the interference at grain boundaries. Additional interference is offered by such amorphous metal layers as may be formed at the slip planes.

The degree of hardening and strengthening by cold-work may be very great, especially when it is possible to carry the working to extremes without causing spontaneous annealing. The following values illustrate the degree of strengthening for various metals. The term "normal" refers to a structure of equiaxed grains of average size:

	Tensile Strength, Lb. per Sq.in.	
Metal	Normal	Severely Cold-Worked
Aluminum	12,000	35,000
Copper	30,000	70,000
Iron	40,000	150,000
Nickel	60,000	250,000 (2 mil. wire)
Molybdenum	85,000	385,000 (2 mil. wire)
Tungsten	Brittle	550,000 (2 mil. wire)
Tungsten	Brittle	700,000 ($\frac{1}{2}$ mil. wire)

The great increase in strength by cold-working can be due to only one cause—the more effective utilization of the inherent cohesion of the metal. This is accomplished by minimizing the effect of the planes of weakness resulting from the normal crystalline structure.

Hardness of Solid Solutions

It is a general rule that metals are hardened and strengthened by the addition of elements which dissolve in them to form solid solutions. Our knowledge of the structure of solid solutions is quite limited, but from the results so far obtained it seems that the atoms of the solute replace those of the solvent without substantial change in the space lattice of the latter, up to the limit of the first or "alpha" solution in case of limited solubility, or the first of a series of solid solutions. This conclusion is based upon studies of alloy series in which the components have similar atomic volumes, and somewhat different conditions may obtain when this criterion is violated. There is good reason to believe, however, that in all cases solid solutions are characterized by the *atomic* dispersion of their components.

When an intermetallic compound forms and dissolves in one of the component metals, it is commonly considered to go into solution "as such." For example, austenite is generally held to be a solution in gamma iron of iron carbide rather than of elementary carbon. This implies that distinct molecules of iron carbide are dispersed in the gamma iron.

From the evidence available, and particularly from a consideration of the phenomena of diffusion, the authors have reached the conclusion that this is not the case, but that the carbon in austenite is present as individual atoms of carbon. These atoms are undoubtedly held strongly to the neighboring iron atoms, but the union is not permanent. Diffusion must consist in a migration of carbon atoms and not of groups or "molecules" containing several iron atoms. Such groups could not, on account of their size, diffuse through solid iron.

According to this view cementite has no existence except as a crystalline substance, which is not merely precipitated but *formed* on the decomposition of austenite. An entirely similar conception is held of other

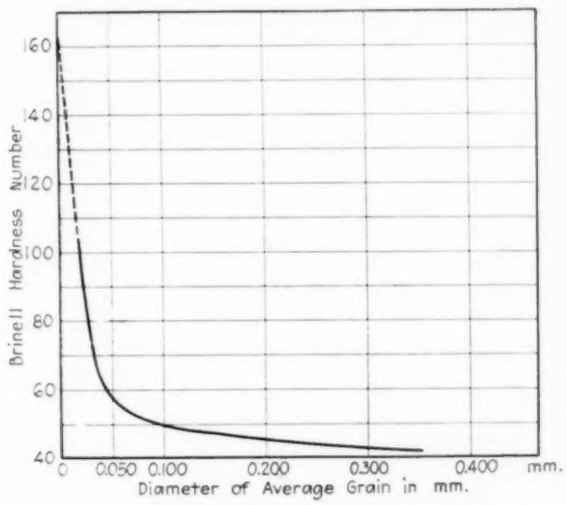


FIG. 2. GRAIN SIZE VERSUS HARDNESS IN ALPHA BRASS, ACCORDING TO BASSETT AND DAVIS

cases involving the solubility of an intermetallic compound, in particular of the case of aluminum and the compound $CuAl_2$, discussed later in some detail.

For the present the essential point is that the dispersion of the components in a solid solution is certainly atomic in many cases and probably atomic in all cases. The increased hardness and strength are therefore traceable directly to increased interatomic forces, the attraction between unlike atoms being in general greater than between like atoms. We may conceive an additional mechanical factor in the form of a roughening of the slip planes due to the presence of atoms of unlike size, or, as Bridgman puts it, a staggered arrangement of the atoms.

Because of the atomic dispersion of the components and the interchangeability of the atoms, it is quite natural that solid solutions should, in general, possess ductility comparable with that of pure metals. They can be deformed plastically by the process of gliding on slip planes and are thereby hardened by the breaking up of their planes of weakness. The hardening and strengthening effects of grain refinement and cold-working apply to solid solutions as well as to pure metals, and are superimposed upon the hardening effect of the solute.

The structural constituents in alloys which possess the greatest specific hardness and strength are the intermetallic compounds and non-metallic compounds such as oxides. The structure of intermetallic compounds is less known than that of solid solutions, inasmuch as the atomic arrangement has not been worked out, to the authors' knowledge, for a single compound of this type. In general, these compounds are of a low order of symmetry, which, together with the large interatomic forces involved, accounts for their great hardness. The atoms are probably arranged in such a way that those of one element are not interchangeable with those of another element. This would account for their lack of plasticity.

One of the most important considerations in the loading

of any brittle material is eccentrically distributed stress. A ductile material subjected to eccentric loading quickly adjusts itself by permanent deformation at any points where the stress exceeds the elastic limit, with comparatively little damage. This is not possible in a brittle substance, and if the stress at any point in a piece subjected to load exceeds the elastic limit, rupture results. It is obviously easier to avoid local overstressing in small pieces than in large pieces. This accounts for the fact that many materials, which are commonly thought of as very fragile, show remarkably high strength when tested in small sections. Vitreous silica, for example, is quite easily broken when in fairly large pieces, although it shows a tensile strength as high as 160,000 lb. per sq.in. in the form of fibers.

This point is important in the present discussion in connection with intermetallic compounds. These substances are as a rule hard and brittle, and are too commonly considered to be weak. Their true strength when properly protected against eccentric loading by their small size and by imbedding in a ductile matrix is undoubtedly very high. We may safely assume that cementite, for example, has a strength of several hundred thousand pounds per square inch.

It has long been recognized that the presence of a hard and strong constituent in an alloy may strengthen it by opposing the "flow," or slip, of the weaker constituent. Just as slip is opposed at the grain boundaries of a pure metal by the change in orientation, it may be opposed to a still greater extent if the material at the grain boundary possesses in addition to its different orientation a specifically greater hardness. The most familiar example of this is the reinforcing effect of the pearlite constituent in hypoeutectoid steels.[4] While pearlite is not a single constituent, it may well be imagined to have an effect like that exerted by hypothetical similar grains of a strong solid solution. The structurally free ferrite is the continuous phase, in which the pearlite is scattered as disconnected islands. If the free ferrite were a structureless amorphous substance, the pearlite could produce only a mild strengthening effect, by a sort of frictional resistance to flow, but the ferrite is crystalline and yields only by slipping on its crystallographic planes of weakness, and such slip is opposed by the rigidity of the pearlite.

This mechanism of hardening, which has been described as the "obstruction principle," refers particularly to reinforcement of a continuous ductile matrix by grains of a stronger constituent which are similar in size to the grains of the matrix. The grains of the matrix are strengthened by *external* support. It has recently become evident that metals can be hardened to a still greater degree by a hard substance dispersed as fine particles *within* the grains.

Aging of Duralumin

A very important incident in the development of the theory of hardening by hard substances highly dispersed is the study of the light aluminum alloys of the "duralumin" type, by Merica, Waltenberg and Scott.[5] The following is typical of the composition of these alloys: Copper, 4.0 per cent; magnesium, 0.5; manganese, 0.5; aluminum (commercially pure), remainder.

These alloys in the rolled or forged condition can be very materially hardened by a heat-treatment consisting of quenching from about 500 deg. C., followed by aging for several days at ordinary temperatures. The hardness and strength immediately after quenching are about the same as in the "annealed" condition, but on aging increase spontaneously about 40 per cent.

Merica, Waltenberg and Scott base their explanation of this hardening on the variation of the solubility of the compound $CuAl_2$ in aluminum with temperature. In Fig. 3 is reproduced a portion of the equilibrium diagram of the aluminum-copper system, showing the solubility curve of $CuAl_2$ in aluminum. It will be noted that the solubility of the compound decreases from about 4 per cent (copper) at 500 deg. C. to probably less than 1 per cent at room temperature. A piece of duralumin examined microscopically immediately after quenching shows a "solid solution" structure—that is, a structure free from visible particles of $CuAl_2$. After the alloy has aged so that the hardness and strength have greatly increased, the structure is apparently unchanged. There is reason to believe, however, that there has occurred

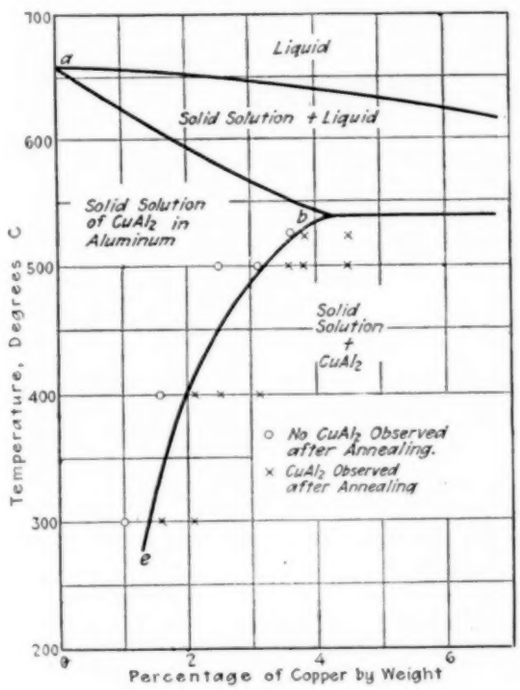


FIG. 3. PORTION OF THE EQUILIBRIUM DIAGRAM OF THE Cu : Al SERIES SHOWING THE SOLUBILITY CURVE OF $CuAl_2$ IN ALUMINUM, ACCORDING TO MERICA, WALTENBERG AND SCOTT

during aging a precipitation of $CuAl_2$ in the form of particles of submicroscopic size, to correspond to the diminished solubility of the compound at the lower temperatures. Quoting from the paper referred to:[5]

"Upon heating a specimen of duralumin that has been quenched from 500 deg. C., but not aged, an evolution of heat occurs at from 250 to 275 deg. C. . . .

"No thermal change takes place upon cooling the same specimen, provided it has not been heated beyond 520 deg. C. Upon reheating the same slowly cooled specimen, no evolution of heat is found corresponding to that upon the first heating. Without doubt, therefore, a chemical reaction takes place at 250 to 275 deg. C. upon heating the quenched sample with evolution of heat—i.e., indicating the formation of stable from unstable phases, not a transformation of stable to other stable phases, the two systems being in equilibrium during the transformation. Such a transformation must take place with heat absorption upon raising the temperature.

"A specimen that has been quenched and aged at from 100 deg. to 150 deg. C. to secure maximum hardness shows little or no evolution of heat upon heating. Whatever may be the chemical reaction that is indicated on the first heating curve of a quenched specimen, it has taken place during

[4] See discussion of the "obstruction theory" in "Metallography of Steel and Cast Iron," H. M. Howe.

[5] "Heat-Treatment of Duralumin," P. D. Merica, R. G. Waltenberg and H. Scott, *Bulletin* A.I.M.E., June 1919, p. 913. CHEM. & MET. ENG., vol. 21, p. 551 *et seq.*

the aging of the specimen, during which the hardening also occurs; stable phases have formed and the subsequent heating curve shows no arrest corresponding to that of the quenched specimen.

"This chemical reaction can hardly be other than the precipitation of $CuAl_2$ from its supersaturated solution in aluminum, although direct visual evidence bearing on this question is also lacking. . . .

"Although it cannot be directly proved that the thermal arrest at about 250 deg. C. noticed upon heating a quenched unaged specimen of duralumin is due to the precipitation of $CuAl_2$, no evidence directly contradicts this assumption, which is in entire accord with our knowledge of the equilibrium within the alloy, and this arrest cannot be assigned to any other phase change.

"It has been shown by many previous investigations and confirmed by the authors that aluminum undergoes no transformation in the solid state between ordinary temperatures and its melting point. No other phase changes could occur in the main mass of duralumin, the grains of solid solution, therefore, except those of solution or precipitation of $FeAl_3$, of the X compound, of $CuAl_2$, of Mg_4Al_3, or of Mg_2Si, within the grains. Aluminum, which contains the same amounts of $FeAl_3$ and of the X compound as does duralumin, is not altered by heat-treatment as is duralumin, nor does it show a reverse heat effect upon heating as does the latter. This heat effect must, therefore, be due to the precipitation either of $CuAl_2$, Mg_4Al_3 or Mg_2Si. But the alloys containing only magnesium in amounts up to 3 per cent also do not harden upon aging. There remains only the precipitation of $CuAl_2$ with which to explain this heat effect.

"The theory outlined above of the mechanism of the hardening of duralumin during aging most readily explains the interesting fact discovered by Mr. Blough and confirmed by the authors that the amount of hardening during aging increases as the temperature of quenching increases. At higher quenching temperatures more and more $CuAl_2$ is dissolved in solid solution. After quenching, the $CuAl_2$ is in excess of its solubility; the higher the quenching temperature the greater is the excess, and this is precipitated during aging. The hardening is in proportion to the amount of the highly dispersed $CuAl_2$ formed.

"If this theory is accepted for the moment, it is interesting to consider the effect of degree of dispersion upon hardness in the case of a solid solution, in this case of $CuAl_2$ in aluminum. Duralumin immediately after quenching is generally softer than it is in the annealed condition. Thus alloy C-11, in the form of sheet, gave the following values of hardness:

	Annealed at 300°	Quenched, but not aged	Quenched, and aged 8 days
Scleroscope hardness, magnifying hammer..	17	16	35

"This is probably due to the fact that a specimen, as ordinarily cooled after annealing, still contains some dissolved $CuAl_2$ in excess of its solubility; the material hardens slightly during cooling. Specimens cooled extremely slowly give a scleroscope hardness of from 7 to 10, much lower than that of the quenched, unaged ones.

"Upon aging a quenched specimen at 200 deg. C., for example, the hardness first increases to a maximum and afterward decreases. During that aging there has been first a formation of fine nuclei of $CuAl_2$ followed by coalescence of these particles into ones of larger size. There is, therefore, a certain average size of particle of $CuAl_2$ for which the hardness of the material is a maximum; atomic dispersion of the solute, $CuAl_2$, is not the dispersion that produces the maximum hardness, but some intermediate one between it and that at which the particles become visible by ordinary means."

An important point in this theory of the hardening of duralumin is the conclusion that there is a certain average size of particle which produces maximum hardness, any size either larger or smaller causing less hardness. This is opposed to the generally held idea that a given amount of a substance added to a metal produces the greatest possible hardening effect when it is in *solution*—that is, when it is in the highest possible state of dispersion. The degree of dispersion conducive to maximum hardness may conveniently be designated by the term "critical dispersion." Dispersions finer than this may be called "sub-critical," and those coarser "super-critical."

It is also important to note the magnitude of the hardening effect in duralumin. It is possible to increase the hardness of pure aluminum approximately tenfold by producing within grains of an aluminum-copper solid solution a critical dispersion of hard particles. This hardening cannot be referred to any of the mystic causes sometimes assigned in the case of steel. The only conceivable explanation is that it is due to the presence of a vast number of very small, hard particles dispersed throughout the grains of aluminum (which probably retain a little copper in true solid solution.

These conclusions regarding the hardening of duralumin naturally suggest seeking analogies in other alloy systems. Merica and his co-authors called attention to the case of steel, pointing out a similarity to duralumin in that the decomposition of a solid solution into particles of sub-miscroscopic size (ferrite and cementite) is involved and also in that some steels (very high-carbon steels and high-speed steels) shown on tempering an *increase* in hardness, followed by the usual decrease. The theory advanced for the hardening of duralumin did not include any explanation of the mechanism by which the particles of $CuAl_2$ cause hardness. Some conception of this mechanism is necessary to any extension of the theory.

The present authors have attempted to analyze the mechanism of this hardening effect, so that the necessary conditions could be defined for all cases. Such analysis involves the explanation, first, of how one constituent dispersed within another produces such great hardness, and second, of why there is a critical dispersion or size of particle which produces maximum hardness.

Easy Slip in Magnetized Plates

In duralumin we are dealing with an aggregate composed of a ductile, relatively weak matrix—aluminum—greatly strengthened by the presence of small hard *disconnected* particles of $CuAl_2$. The strength attained in the duralumin must be derived from the inherent cohesion of the continuous aluminum matrix. There is no conceivable way in which a few per cent by volume of a strong constituent in disconnected particles could impart a new element of cohesion of the magnitude actually obtained. Their action must consist in rendering more effective the cohesion latent in the aluminum. The logical inference is that this is accomplished by the elimination of extended planes of weakness—that is, by slip interference.

In Fig. 4 is represented a section through a crystal, the fine parallel lines representing a set of planes of easy slip. It may assist in obtaining a concrete conception of the mechanical conditions to consider a stack of iron plates placed in a strong magnetic field at right angles to their surfaces. It would be very difficult to pull these plates apart by a straight tensile effort, but comparatively easy to separate them by sliding them over each other. This stack of plates presents a rather close analogy to the conditions obtaining in a ductile crystal, especially in that the forces which hold the atoms of a crystal together are probably electro-magnetic in character.

In separating the magnetized plates by a straight pull it is necessary to overcome the entire magnetic attraction at once, whereas in sliding the plates the magnetic force is overcome only at the edges and then gradually by small increments. The principal resistance due to sliding is the frictional resistance of the plates due to the pressure. In order completely to separate the portions of a crystal on opposite sides of a plane of slip by a direct tensile pull it would be necessary to break simultaneously all the atomic

bonds on the plane. This would require a force equal to the absolute cohesion of the metal. The two portions can move with respect to each other on the slip plane without permanent rupture of any considerable proportion of the atomic bonds. Of course, extended slip separates the atoms from their old neighbors, but cohesion bonds are established with their new neighbors. The separation of the magnetized plates by a direct pull results in a "brittle" fracture with a minimum work of rupture. When the plates are separated by sliding, the work of rupture is increased by an amount equal to the frictional losses. Similarly when a crystal is fractured in a brittle manner the work of rupture is a minimum, whereas in a ductile fracture the work of rupture is markedly increased due to the friction at planes of slip.

Small Hard Particles Act as Keys

Fig. 5 shows an ideal section through a crystal in which it is supposed that a hard, strong substance is dispersed in the form of substantially spherical particles. These particles are supposed to be about equal in size, but of course the circles cut by the plane of the section should be of different sizes according to the distance of this plane from the centers of the spheres. It will be noted that there is not a single plane of easy slip which does not encounter at least one of these hard particles. Under the action of an external load tending to produce slip along these planes, the hard particles must act as *keys*, mechanically obstructing any motion along the planes as a whole. The result is increased elastic limit, hardness and strength.

Now suppose all the hard particles to be gathered into a single large particle, as shown in Fig. 6. Although the size and strength of the "key" are greatly increased, there are many planes of weakness left without any reinforcement. The single large particle does not interfere with slip on these planes. It is easily seen that the strengthening effect of the hard particles increases with their *number* and not with their size. Even in case all possible planes of slip are keyed at some points, more effective slip interference must result from diminishing the size and increasing the number of the particles. We thus have the rule that the hardening effect of a given amount of hard dispersed substance is greater the smaller the particles. This rule must reach a limit as the particles approach atomic dimensions. We do not know how small a crystal may be and still possess the characteristic hardness and strength of the substance.

Let us consider the strength of true solid solutions or atomic dispersions from the point of view of the slip interference theory. Planes of weakness are present just as in the pure metal or solvent. At intervals the succession of atoms of solvent is interrupted by an atom of the solute. At each point where an atom of the solute occurs there is an increased bond, or, we might say, pressure, on the plane of potential slip, due to the greater force of attraction between the unlike atoms. This constitutes in effect a key, very much as to do the crystalline particles of $CuAl_2$ in aluminum. The planes are seemingly "spot welded" together by the atoms of the solute.

The experimental evidence indicates that the formation of crystalline nuclei of $CuAl_2$ in duralumin, from the solid solution of copper in aluminum, causes an increase in hardness and strength. If the key action of the atomically dispersed copper were equivalent to that of the crystalline particles of $CuAl_2$, we should not expect this to be the case, since the hardness should increase as the *number* of keys increases. It is quite natural to suppose that the attractive forces of the copper and aluminum atoms for each other are not brought fully into play until the atoms are arranged in their most stable arrangement—that of the compound. The key formed by the little group of aluminum atoms surrounding the copper atoms in the solid solution is more easily sheared through than is a particle of crystalline $CuAl_2$. The critical dispersion for maximum hardness should therefore consist of the smallest possible particles having the characteristic crystallinity of the compound. If we classify particles according to their diameters in terms of atoms, the following probably represents approximately the sizes involved:

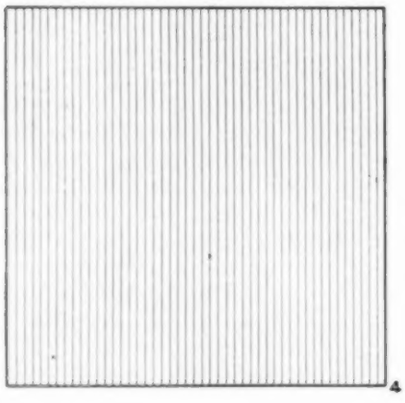
1 atom diameter	solid solution	somewhat hard
10 atom diameters	critical dispersion	hardest
1 000 atom diameters	smallest visible particles	somewhat soft

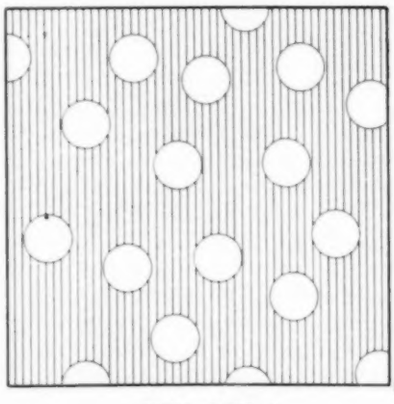
Number of Keys in a Duralumin Crystal

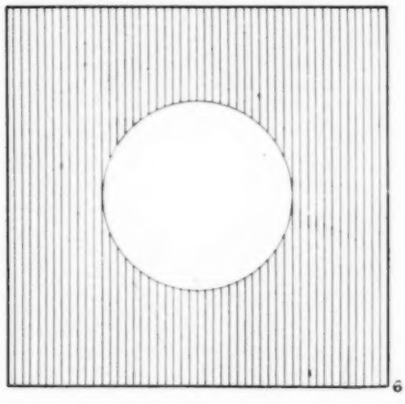
Let us take for an example the hardness changes in a duralumin alloy containing 4.5 per cent Cu. This alloy would contain 2 atoms per cent of copper or 8.33 weight per cent of $CuAl_2$ assuming that all of the copper is present as that compound. This would be at most 5.4 per cent $CuAl_2$ by volume; actually it is less than that amount, inasmuch as some of the copper will always be in solution. When the worked alloy is heated to a temperature at which all of the copper is in solution and then quenched, the hardness will be about 80 Brinell. The copper is probably in atomic dispersion. On aging, the hardness can be increased to about 140 Brinell as the $CuAl_2$ precipitates and the particles reach critical size. By very slow cooling from high temperatures the hardness can then be reduced to about 50 Brinell. Such a hardness is produced only after the $CuAl_2$ particles have reached relatively large sizes.

Tensile strength varies with the hardness. The plasticity is the greatest in the freshly quenched condition and the least when the $CuAl_2$ particles are present in critical size. The high plasticity accompanying atomic dispersion of copper would be expected, because the areas of potential slip planes will depend on grain size only. The interference to slip is greater than in pure aluminum; it resides in the nature of greater pressure between the two slip surfaces, but the planes are relatively smooth.

An average sized grain of duralumin would have about 2 000,000,000 atoms of copper on each potential slip plane. Although we do not know exactly the percentage of the







FIGS. 4 TO 6

Fig. 4. Set of planes of easy slip in a crystal having no internal slip interference. Fig. 5. Slip planes "keyed" by hard particles. Fig. 6. Hard constituent gathered into a single large particle, leaving many planes, without reinforcement.

copper precipitating as $CuAl_2$ during aging, we can for convenience consider it as 75 per cent of that present. Assuming now that the $CuAl_2$ particles have reached an average size of one ten-millionth inch diameter there will still be 500,000,000 copper atoms on each of the above planes and in addition each plane will be keyed with the relatively hard $CuAl_2$ particles at 35,000,000 to 40,000,000 places. This condition corresponds nearly to critical dispersion. By the time the $CuAl_2$ particles have reached an average diameter of a hundred-thousandth of an inch, each of the above planes will be keyed in about 3,500 to 4,000 places; if the diameter were further increased one hundred times only about three planes out of eight would be keyed at all!

The presence of a given amount of hard substance in large particles produces excess slip interference locally, but leaves portions of the metal in a weak condition. Cohesion of the mass as a whole is therefore gained by subdivision of the key material into many particles distributed as uniformly as possible. The weak links of the chain of slip planes are thus strengthened at the expense of the strong ones. Plastic deformation in such a material produces an intricate system of slip planes determined by the number and size of the particles. In many places the slip cannot follow the easy crystallographic planes, but is forced to take place in unfavorable directions. The quantity of dispersed substance may be so great that the resistance to slip becomes equal to or greater than the direct rupturing strength of the atomic bonds, and brittleness accompanied by relatively great hardness will result.

Fig. 7 is a micrograph of a high-carbon steel in which the cementite has been coarsely spheroidized. One can readily see what an intricate system of slip planes or flow surfaces must be produced in this structure by plastic deformation. Fig. 8 shows this structure at higher magnification (650 diameters) after plastic deformation. It will be noted that the slip avoids the cementite and that the surfaces of slip are rough. The appearance is intricate as opposed to the systems of regular slip planes in nearly pure metals shown below in Figs. 9 and 10. As compared to critical size, the particles of cementite shown in Figs. 7 and 8 are very coarse. Each of the larger particles of cementite shown in these micrographs would have to be subdivided into about 1,000,000,000 particles to reach critical dispersion. The intricacy of the system of slip planes would correspondingly increase.

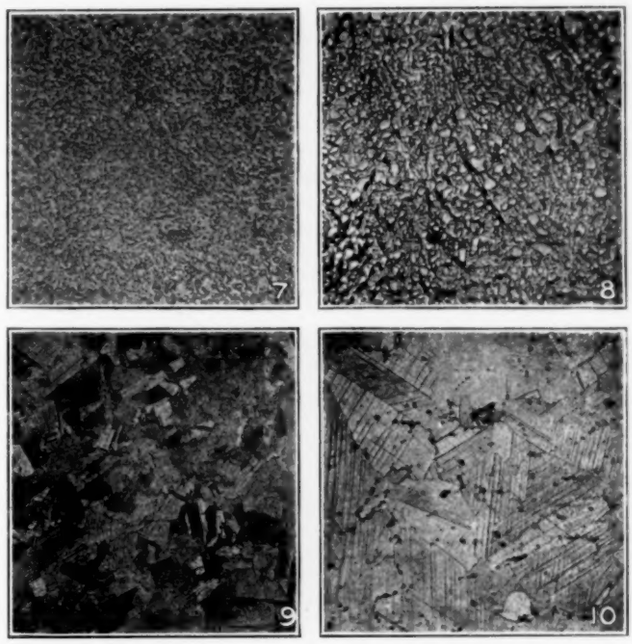
Adhesion Between Constituents

While the $CuAl_2$ and Fe_3C particles probably have rather strong adhesion for the aluminum and iron respectively, such adhesion need not obtain in order to produce hardening. Copper oxide often present in copper should have very little adhesion for the metal, but when it is present in the form of globules within the copper grains it produces a strengthening effect. Antisell[6] states that 0.2 per cent (1.8 per cent Cu_2O) oxygen increases the tensile strength of annealed copper over 10 per cent. Figs. 9 and 10 show a small quantity of Cu_2O. The particle size is large as compared to critical dispersion. In fact there is no way known to produce a very fine dispersion of the Cu_2O, and hence we cannot greatly harden copper by its presence in relatively small quantities. It will be noted that the slip planes in Fig. 10 have a tendency to extend completely across the grains. Yet slip planes in general avoid the Cu_2O particles or are faulted or stopped by them.

This represents the first stages of slip interference.

Thorium dioxide probably has little adhesion for tungsten, but when 1.5 per cent by volume is present as particles within the grains the tensile strength is increased in the temperature regions within which the metal is ductile. The presence of the thoria also has

[6] "Relationship of Physical and Chemical Properties of Copper," Frank L. Antisell, A.I.M.E., *Bull.* 157.



FIGS. 7 TO 10

Fig. 7. High-carbon steel. Cementite coarsely spheroidized. × 150. Fig. 8. Showing plastic deformation in high-carbon steel with spheroidized carbide. × 650. Fig. 9. Slip bands in copper. × 30. Fig. 10. Slip bands in copper. × 150.

the effect of increasing the tensile strength more for a given amount of working below the annealing temperature than in pure tungsten. The cases of Cu_2O in copper and ThO_2 in tungsten are important, because they give positive evidence of the strengthening effect of these mixtures in which a weakening might be expected due to decrease of the effective cross-sections of the metals.

In all of the cases mentioned above the hardness has been produced by dispersing *hard* particles within relatively large grains of metal. We should not expect *soft* particles to produce hardening, because the "keys" of soft substance would shear and thus assist rather than oppose slip. The term *soft* is used here in the relative sense only.

Similarity of Manganese Steel and Duralumin

The explanations of the hardening of duralumin and of hardening by grain refinement are so simple and logical that we should examine the phenomena of the hardening of steel from the same viewpoint. The fact that iron is capable of existing in at least two crystalline forms makes it difficult to differentiate between cause and effect and to appraise the true significance of the "critical" changes. The case of duralumin might be equally difficult to understand if hardening by heat-treatment were accompanied by allotropic and visible structural changes. Hardening of duralumin does not involve an allotropic change, twinning, or even a refinement of grain.

Its study teaches us that a soft crystal of aluminum can be hardened by dissolving copper in it; that the aluminum-copper solid solution can be further hardened by the precipitation of some of the copper into minute particles of $CuAl_2$; that maximum hardness is produced when the precipitated compound is present in particles of a small (critical) size, certainly much less in diameter than 1,000 atoms; that when the particles become larger than the critical size the hardness decreases as the particle size increases. The percentage increase in the hardness of aluminum by proper alloying and heat-treatment is comparable to that obtained in iron by alloying with carbon and heat-treatment.

If manganese steel containing from 1.0 to 1.5 per cent C and 13 per cent Mn is quenched from a high temperature, the structure existing at the high tem-

perature is preserved at room temperature. The result is an aggregate of grains of austenite, which is in this case gamma iron with the carbon and manganese dissolved in it. The hardness is about 160 Brinell, a very substantial increase over pure alpha iron (75). The austenitic structure is stable unless the manganese steel is cold-worked or heated. The hardness increases on tempering and may reach about 500 Brinell after suitable heat-treatment. As the steel hardens it becomes magnetic, but not in proportion to the increase in hardness—in fact most of the hardening occurs before the steel has reached 2 per cent specific magnetism[7] and before there is much visible change in the structure of the austenite.[8]

If a piece of this steel be heated to 1,100 deg. C. and cooled slowly, a network of carbide, presumably a mixture or solution of cementite and manganese carbide, is formed. Austenite at temperatures around 400 to 600 deg. C. is supersaturated with carbon, since the carbides precipitate around 500 deg. C. into particles large enough to be seen with a microscope.

Since the dispersion of the carbon is atomic in the austenite, it does not offer maximum interference to slip. The austenitic manganese steel is therefore relatively soft and ductile: the carbon dispersion is subcritical. The formation and precipitation of carbides into particles of visible size show that every size between molecular and visible must have obtained at some previous stage. The critical size or dispersion must have been reached prior to the appearance of the visible particles. Carbide of iron is magnetic and hence slight magnetism might appear on annealing, accompanied by a considerable increase in hardness, without producing a transformation of any appreciable amount of austenite into alpha iron. This latter transformation proceeds slowly, however, and its effect is superimposed on that resulting from the carbide precipitation.

Transformation into alpha iron produces an entire change in structure and a decided increase in magnetism, but the hardness may increase or decrease. Extended exposure to temperatures around 650 deg. C. eventually produces softening.

It is thus seen that in the early stages of hardening manganese steel the changes are strikingly similar to those found in the hardening of duralumin.

Grain Refinement in Quenching Steel

There is an important factor accompanying the changes from austenite to granular pearlite which is absent in duralumin—namely, change in grain size of the matrix. When pure iron is quenched from above 900 deg. C., the ferrite grain size is smaller than that produced by slow cooling. As the carbon content is increased the ferrite grain size produced by quenching from above the upper critical progressively decreases. When the carbon content exceeds about 0.2 per cent the structure may all be martensite, in which the iron exists in the crystalline magnetic (alpha) state, but in most cases no definite grains of ferrite can be detected under the microscope.

As pointed out previously, reduction of grain size is itself an important factor in hardening. The quantitative significance of sub-microscopic grain size has been no better understood or appreciated than that of reducing dispersed particle size to approach atomic dimensions. By extrapolation in Mathewson's[9] formula it is found that the hardness of alpha brass could be increased to 300 Brinell (nearly twice the hardness of cold-worked alpha brass), if a grain size of about $\frac{1}{250,000}$ in. diameter could be produced. Each grain would then comprise about 100,000,000 atoms. There is no way known to produce such fine grain size in alpha brass and consequently we cannot develop such hardness. The results given above on tungsten, molybdenum and nickel indicate, however, that this figure is probably not higher than the absolute cohesion of the alloy. According to the general proposition that the absolute cohesion of a pure metal is sufficient to account for the hardening produced in alloys of that metal, it should be possible to produce hardening by reduction of grain size alone to an extent comparable to that produced by the critical dispersion of hard particles in relatively large crystals.

The change of properties of the nickel-iron alloys by heat-treatment is of especial importance in connection with the effect of change of grain size alone. An iron-nickel alloy containing 7.54 per cent Ni, 0.09 per cent C and 0.04 per cent Mn had its strength more than doubled by quenching from a dull red heat.[9] Edwards concludes from a general review of the work on iron-nickel alloys that the presence of carbon is not necessary in order for such hardening to take place on quenching. Nickel lowers the transformation temperature of iron to such an extent that the quenching of a 7.5 per cent nickel alloy produces great grain refinement. The quenched product might be termed a carbonless martensite. Thus we have in certain iron-nickel alloys without carbon marked hardening accompanied by a great reduction in grain size. This is a simple case where the hardening is due to one factor—namely, reduction of grain size—whereas in duralumin and probably in the first stages of the hardening of manganese steel this factor does not enter, the hardening being attributable to a fine dispersion of hard particles within ductile crystals. These two factors may occur simultaneously in ordinary steels, making possible the many variations in their properties by heat-treatment.

Martensite Is Alpha Iron

In austenite we assume that the carbon is quite uniformly distributed in atomic dispersion. When austenite is quenched to form martensite, the short time and low temperature of transformation favor the retention of a large amount of the carbon in atomic dispersion in the ferrite. The transformation of austenite at Ar_1 under equilibrium conditions involves a change of the gamma iron to alpha iron and the combination of the carbon with iron to form cementite (Fe_3C). The latter would not form unless the iron changed its crystal structure. Therefore the allotropic transformation of the iron is the cause and the formation of cementite is the result. The change in iron involves no substantial migration of atoms, while the formation of cementite does. The logical order for the transformation to take place in eutectoid and hypo-eutectoid steel is first the iron transformation and then the cementite formation. When austenite is slowly cooled through A_1, the two changes occur so close one after another as to be called simultaneous. When the cooling rate is proper to form troostite, physico-chemical equilibrium but not structural equilibrium results—that is, the ferrite and cementite both form but in such small particles that heating to temperatures slightly under A_1 (500 to 700 deg. C.) causes marked structural change.

When the cooling rate of the austenite is sufficiently rapid to form martensite, the transformation of the gamma iron to alpha is substantially complete, whereas the formation of cementite is not complete.

[7] Iron equals 100 per cent.
[8] "Metals and the Common Alloys," S. L. Hoyt, pp. 347-349.
[9] "Physicochemical Properties of Steel," C. A. Edwards, p. 164.

Martensite should therefore consist principally of sub-microscopic ferrite grains containing carbon in solution. The carbon content of the mother austenite will strive to precipitate as particles of Fe_3C, and the extent of this reaction will depend on the temperature-time conditions during quenching, aging and tempering.

The following are the reasons for concluding that the formation of martensite from austenite represents a change from gamma to alpha iron:

1. The complete change in microstructure of martensite, as compared to that observed when austenite is preserved on quenching, indicates a transformation of gamma iron.

2. The magnetism of martensite suggests the presence of crystalline magnetic (alpha) iron.

3. The X-ray spectrometer proves that alpha iron is the chief constituent of martensite. Steels which are non-magnetic show face-centered cubic lattices with the X-ray spectrometer, whereas martensite, which is magnetic, shows a body-centered cubic lattice. A 1.5 per cent C steel quenched from above the critical in iced brine showed both martensite and austenite under the microscope, and the X-ray spectrometer pattern showed both face- and body-centered lattices. A 0.35 per cent C steel quenched from above Ac_3 showed only martensite under the microscope and only a body-centered lattice with the X-ray spectrometer.[10]

There are other considerations which suggest that the transformation from austentite to martensite represents a substantially complete change from gamma to alpha iron, but in view of the definiteness and finality of the results of the X-ray spectrometer, no other evidence need be considered.

Martensite Crystals Are Submicroscopic

Having established the fact that martensite consists chiefly of crystalline iron of the alpha modification, we conclude that the ferrite is present in grains of submicroscopic size for the following reasons:

1. The conditions obtaining at the time of the formation of martensite are conducive to the production of small grains.

2. In low-carbon martensite formed from coarse grained austenite, ferrite can often be seen under the microscope in the form of very small plates.

3. In higher carbon steels which are conducive to the formation of finer grains on quenching, no ferrite can be resolved under the microscope.

4. In order to obtain a good Hull pattern[11] with the X-ray spectrometer it is necessary that the specimen be fine grained. In a 0.35 per cent C martensite, formed by quenching from 1,300 deg. C., the alpha iron pattern was typical of that obtained from fine-grained metals, even though the austenite grains from which the martensite was formed were large enough to be seen with the unaided eye.

It is not to be understood that the ferrite grains in martensite are necessarily equiaxed. The conditions obtaining during their formation are conducive to the production of very small plates of ferrite running parallel to the cleavage planes of the austenite. Whether the grains are substantially equiaxed or in plates, the precipitation along the austenite cleavage planes gives rise to the acicular structure of martensite. The tendency for this cleavage precipitation is so marked that martensite formed by quenching large grains of austenite appears under low magnifications to have a grain structure similar to that of the austenite. Detailed examination, however, reveals the fact that the austenite grain structure is entirely replaced by a structure so fine that it is often impossible to find a single crystalline particle large enough to see with a high-powered microscope. The apparent crystalline masses observed after light etching are seen to be, after deep etching, complexes of very fine structure.

No Cementite in Martensite

The reasons for concluding that the austentite-martensite transformation does not represent a complete formation of the cementite are: (1) The heat evolved when martensite changes to troostite. (2) The failure to detect the presence of cementite in untempered martensite by magnetic analysis.[12] (3) The etching characteristics of martensite as compared to troostite suggest that the carbon is in solution in the former and is largely present as cementite in the latter.

The authors believe that it is the carbon rather than the carbide in solution in the ferrite of the martensite for the same reason that they believe that it is the carbon and not the carbide which is in solution in austenite. Cementite can form in martensite only by the migration of carbon atoms. In order for these to migrate freely they cannot maintain contact with any particular iron atoms. In freshly formed martensite therefore most of the carbon should be atomically dispersed, but a small amount may actually be in the form of particles of cementite. The presence of the carbon assists in the hardening indirectly by helping to produce a very fine ferrite grain size and directly by strengthening the ferrite grains.

Although the ferrite of the martensite is held to contain carbon in solution, it is considered that the fineness of grain is chiefly responsible for the hardness.

Great hardening can be produced with 0.40 per cent C, which is 1.9 atoms per cent. No case is known with large-grained metals where 1.9 atoms per cent of one element dissolved in a metal produces hardening at all comparable with that of a 0.40 per cent C martensite. In austenitic manganese steel there may be as much as 7 atoms per cent of carbon and 13 per cent manganese (by weight) dissolved in gamma iron without producing marked hardness. The structure in this case is coarse grained. It may be argued that 0.40 per cent carbon produces 6 per cent of cementite and that it is this compound which is in solid solution in the ferrite. The same argument applies to manganese steel which would have over 20 per cent of cementite in solid solution. If, therefore, we assume solution of the carbon in the ferrite of the martensite it follows that the grain refinement must be the principal cause of the hardness. Experimental evidence points conclusively to a super-refinement of the ferrite grains and favors the conclusion that the greater part of the carbon has not formed into carbide.

The hardness of martensite may therefore be attributed chiefly to a combination of two factors—namely: (1) The super-refinement of the ferrite grains, and (2) the strengthening of the ferrite by carbon.

Too little is known regarding the exact sequence of hardness changes on tempering quenched carbon steels. The most marked effect is one of softening, and the opinion is fairly general that softening is progressive throughout the whole range of tempering temperatures. It is certain that the tempering of hardened tool steel at temperatures above 200 deg. C. reduces its cutting hardness and probably also its Brinell hardness. The Shore scleroscope hardness of tool steel seems to be less affected by tempering at low temperatures. It is likewise quite certain that steels of medium carbon content which have been hardened are softened by tempering at temperatures above 350 deg. C., as proved by thou-

[10] Preliminary results of work done by Jeffries and Bain.

[11] "The Crystalline Structure of Metals" by Jeffries and Archer, CHEM. & MET. ENG., vol. 24, p. 776 (May 4, 1921).

[12] K. Honda, "On Magnetic Analysis as a Means of Studying the Structure of Iron Alloys," *J. Iron & Steel Inst.*, No. 2, 1918, pp. 375-419.

sands of tests on hardness and tensile strength. The hardness of low-carbon steels is known to be not greatly changed by tempering, and the changes brought about by tempering above 500 deg. C. are certainly in the direction of softening. Steels of the various carbon contents are seldom tempered commercially at temperatures below those which produce easily measureable softening. There is, therefore, a lack of results of commercial practice in the tempering of hardened steels at very low temperatures.

It is stated by Heyn and again by Boynton that tempering, even in its early stages, gradually reduces the hardness of martensite. Heyn's conclusions are drawn from scratch hardness tests on high-carbon steel. Among the few published contributions on this subject is a paper by C. Grard[13] in which it is reported that the first effect of tempering is to *increase* the hardness.

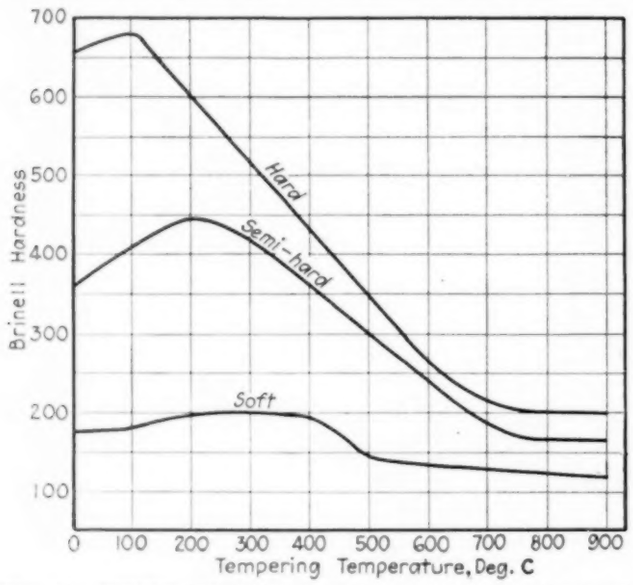


FIG. 11. EFFECT OF TEMPERING ON THE HARDNESS OF HARDENED STEEL (GRARD)

His results are plotted in Fig. 11. They are described as typical of the steels of the classes named. No analyses are given.

While Grard's curves are opposed to general opinion, it is believed that they merit serious consideration as representing perhaps an overlooked phenomenon in the tempering of steel. He appears to have made a particular point of the accuracy of his hardness determinations. These were also confirmed, in the case of the soft and semi-hard steels, by tensile strength results which parallel the hardness results closely; hard steels were too brittle for satisfactory tensile tests after low tempering temperatures. It is to be noted that the maximum hardness attained on tempering occurs at a lower temperature the higher the initial hardness. Marked softening also begins at lower temperatures the higher the initial hardness.

According to the critical dispersion ideas the precipitation of cementite in martensite should produce an increase in hardness. Cementite meets all of the requirements of a good "key" material.

At some stage in the formation and growth of cementite particles, conditions would be proper to produce maximum hardness. It is not probable that all of the cementite particles have critical size at the same time. At any given time in the first stages of tempering, some particles should be super-critical, some critical and some sub-critical. It must be considered also that alpha iron has some solvent power for carbon under equilibrium conditions; all of the carbon therefore cannot form into cementite.

After the cementite formation has progressed nearly to completion the larger particles grow by absorbing carbon in solution in the ferrite. The ferrite will be supersaturated in carbon with respect to large particles and saturated with respect to small particles of cementite. The precipitation of the carbide on the larger particles produces a condition of undersaturation with respect to the smaller particles which then are dissolved. The carbon atoms diffuse toward regions of low concentration, which is toward the larger particles.

Growth of cementite crystals during tempering is favored by long time and high temperature. The successive stages of troostite, sorbite and granular pearlite represent in part progressive increase in size and decrease in number of the cementite particles.

Changes in Ferrite on Tempering

As the carbon changes noted above are progressing there must be some change in the ferrite. In the case of a steel containing 1 per cent carbon the formation of cementite will require about 15 per cent of the iron. This iron must be supplied from the ferrite or from any amorphous iron which may be present. Such a change would tend toward a more perfect equilibrium in the ferrite which would tend toward softening. It seems certain that the growth of the ferrite into larger particles at temperatures from 350 to 550 deg. C. is an important factor in the decrease of hardness. The effect of changes in the ferrite caused by low-temperature tempering (below 300 deg.) is small, but even this becomes appreciable in the harder martensites.

Martensite cannot be hard without being fine grained and in general the greater hardness will be produced by the greatest grain refinement. The finer the grains the lower should be the temperature at which structural changes begin on tempering, and hence this factor should cause martensite to soften considerably by prolonged heating at temperatures well below 300 deg. C.

The first stages of the tempering of martensite therefore involve two opposing factors; the changes in the ferrite tend to produce softening while the first precipitation of the cementite tends to harden. We might expect an increase or decrease in hardness according to the rapidity and extent of these opposing changes.

If low-temperature tempering does not produce a change in hardness, it should not be prematurely concluded that no internal changes had taken place. It is quite conceivable that in Prof. Campbell's[14] steels heated twelve hours at 100 to 108 deg. C. the hardness changes were insignificant, yet the electrical resistivity had decreased 25 per cent. Such a change is consistent with the breaking down of a solid solution into two constituents. The extensive work of Barus and Strouhal[15] also shows that even heating for an hour at 66 deg. C. produces internal changes in hardened steel. A structural change and change in electrical resistivity might obtain and the hardness might increase, remain constant or decrease in accordance with the relative magnitude of these opposing factors.

Any austenite which may be present in a quenched steel will further complicate the results produced on tempering. The transformation of austenite on heating is always accompanied with hardening. As a rule the lower the temperature at which the transformation will take place the harder will be the transition product. Mauer[16] found, for example, that austenite containing 1.94 per cent C and 2.24

[13] "Research on the Hardness of Steel," Captain C. Grard. *Proc.* 6th Congress Inst. Assoc. for Test. Mat. III$_2$.

[14] E. D. Campbell, "On the Rate of Change at 100 Deg. C. and at Ordinary Temperatures in the Electrical Resistance of Hardened Steel," *J. Iron & Steel Inst.*, No. 2, 1918, pp. 421-428.

[15] *Bull.* 14, U. S. Geologic Survey (1885).

[16] "Investigations on the Hardening and Annealing of Iron and Steel," *Metallurgie*, vol. 6, 1909, pp. 33-52. Ed. Mauer.

Mn transformed at 400 deg. C., while a steel containing 1.66 per cent C and having a structure of two-thirds austenite and one-third martensite showed the transformation at 250 deg. C. The latter had very much higher maximum hardness. This accords with the observation that austenitic manganese steel transforms only at a relatively high temperature and never attains extreme hardness.

Nature of Troostite and Sorbite

The constituents troostite, sorbite and granular pearlite represent different degrees of subdivision of the ferrite grains and the cementite particles. As the tempering temperature is increased up to A_1 and as the time of exposure at temperature increases the ferrite grains and the cementite particles become larger. These two factors now combine to soften and weaken the steel. The slip interference theory discussed above explains nicely the decrease in hardness as the constituents become coarser. The hardness of a tempered martensite will be affected indirectly by the quantity of carbon, because cementite opposes ferrite grain growth, and directly by the slip interference caused by the cementite. It is because the presence of carbon has this double (direct and indirect) hardening effect that the physical properties of heat-treated steel vary so much with change in carbon content and with change in heat-treatment. For example, pure iron has a hardness of about 75 Brinell, whereas troostite containing about 0.9 per cent C may have a hardness of 500. The hardness of the troostite is due partly to the mere presence of cementite and partly to the ferrite grain refinement caused by the cementite.

Obviously the alloy steels are more complex than the carbon steels. In general the hardening alloy ingredients help to produce martensite at slower rates of cooling than would be possible in carbon steels. They also strengthen the ferrite by their presence in solid solution and may change the nature and degree of dispersion of the hard particles that are produced on tempering.

Restatement of Theory

Although there is substantial agreement among metallographists regarding the nature of troostite, sorbite and granular pearlite, there has been a constant controversy for the last thirty-five years regarding the nature of martensite. Many theories have been put forward and volumes have been written on this subject.

No attempt will be made here to discuss these various theories. It may be mentioned that the authors made their analysis of this problem without consideration of any of the current theories. While the conclusions reached regarding the nature of martensite do not correspond completely to any current conception, they correspond in the main to a combination and extension of the ideas of Grenet[17] and M'Cance.[18]

Owing to the X-ray spectrometer results the conclusions regarding the allotropic changes can now be considered as established. It is obvious that the "beta iron" theory has little foundation. Even if beta iron is a true allotrope there is no evidence that it is hard or that it is present in martensite. The theory advanced by Edwards and Carpenter[19] that martensite represents twinning in gamma iron is also untenable, for the reason that martensite consists chiefly of alpha iron. The "solid solution" and "carbon" theories are unsatisfactory, because they are indefinite and incomplete.

The ideas regarding the nature of martensite presented in this article not only accord with observations of fact and fulfill the requirements of logic and simplicity, but a concrete mechanism is put forward showing how the structures postulated are able to account for the hardness of quenched steel and the changes in properties on tempering.

Summary

A complete theory of hardening must explain hardness in non-allotropic metals, a task which has been attempted in the preceding pages, and is summarized below:

1. The inherent cohesion of the pure metals is far in excess of values obtained for tensile strength.
2. Mechanical failure under stress is ordinarily premature because of the presence of crystallographic planes of weakness, or potential slip planes.
3. Any structural condition which interferes with slip on these planes of weakness increases the strength and hardness of the metal. Furthermore, every known method of hardening metals can be referred to this principle of "slip interference."
4. In a pure metal the most simple source of increased hardness is grain refinement, which introduces slip interference at the grain boundaries due to the different orientations of the adjacent grains, and, especially in fine grained metals, to the disorganized or amorphous metal between the grains.
5. Cold-working introduces slip interference by the fragmentation of the grains and the production of amorphous metal.
6. The hardness and strength of amorphous metal itself is due to the absence of the planes of weakness characteristic of crystals.
7. Slip within grains is opposed by the presence of a strong constituent at the grain boundary, providing that if the strong constituent is brittle, its shape and size are not such as to lead to effective weakness due to eccentricity of loading.
8. Effective hardening is obtained by slip interference within the grains, due to the presence of hard constituents uniformly distributed in the form of very fine particles.
9. It is not necessary that the hard constituent possess great adhesion for the matrix.
10. The effect of a given amount of hard constituent increases with the fineness of subdivision, reaching a maximum at an average particle size denoted by the term "critical dispersion." The critical dispersion probably consists of the smallest particles having the characteristic properties of the crystalline substance. The order of magnitude of the diameter of such particles is probably about 10^{-7} cm. A higher degree of dispersion, particularly the atomic dispersion of solid solutions, is less conducive to hardness.
11. Corresponding to the maximum hardness at critical dispersion, there is a minimum in ductility.
12. Increase in the amount of dispersed substance produces increased hardness, but the brittleness also increases, so that there is a limit to the useful hardness and strength that can be obtained.
13. The amount of hard dispersed substance which produces the greatest useful strength increases as the size of particle increases.
14. The actual amounts of hard dispersed substances which produce useful results are from about 2 to 15 per cent by volume.
15. The only manner in which the high degrees of dispersion desired are produced consists in the limited decomposition of solutions, and in particular of solid solutions.
16. Martensite consists of a solid solution of carbon in very fine-grained alpha iron. The hardness is due chiefly to the grain refinement of the ferrite, but partly to the carbon in solution.
17. The tempering of martensite involves two changes: ferrite grain growth and the precipitation and growth of cementite particles. Ferrite grain growth causes progressive softening. The precipitation of cementite causes hardening, but the growth of the particles above the critical size produces softening.

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[17] Grenet, "The Transformations of Steel Within the Limits of the Temperatures Employed in Heat-Treating," *J. Iron & Steel Inst.*, No. 2, 1911, pp. 13-75.

[18] A. M'Cance, "A Contribution to the Theory of Hardening," *J. Iron & Steel Inst.*, No. 1, 1914, pp. 192-265.

[19] C. A. Edwards and H. C. H. Carpenter, "The Hardening of Metals, With Special Reference to Iron and Its Alloys," *J. Iron & Steel Inst.*, No. 1, 1914, pp. 138-191.

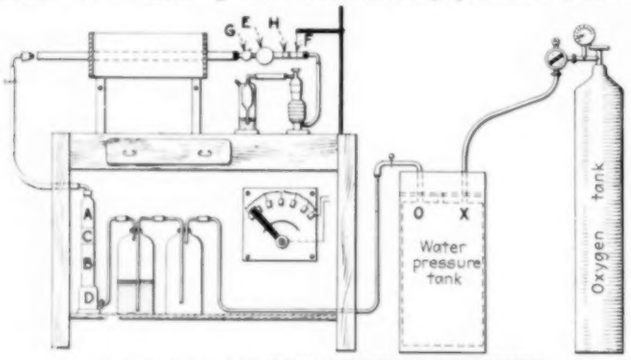
A Simplified Carbon Combustion Train

By W. W. Boone*

THE estimation of carbon in steel has probably attracted more attention than that of any other element, due to its far-reaching influence upon the properties of the steel. At present the three most general methods used are: (1) Color comparison; (2) direct combustion; (3) wet combustion. For all ordinary steels the direct combustion of the steel in a current of oxygen is the most rapid and accurate method known. The color comparison method is very inaccurate in many cases, and the wet method entails the use of bulbs and apparatus too fragile and delicate for technical purposes.

In designing a simplified combustion train the writer has endeavored to eliminate all non-essentials for ordinary steel analysis, and at the same time make the train as nearly foolproof as possible. The apparatus is shown in the accompanying figure.

In most trains the flow of oxygen is regulated by means of a reducing valve and mercury pressure gages.



SIMPLIFIED CARBON COMBUSTION TRAIN

This scheme, however, requires frequent juggling of the reducing valve during the same determination, especially during the period of combustion, and hence the pressure and flow vary considerably.

By the insertion of a water-pressure tank a practically uniform pressure is maintained throughout the combustion. This tank is of galvanized iron 12 in. in diameter and 36 in. in height, with an open top. Another shell 30 in. in height telescopes into the first tank and is fastened securely in position by means of a rod imbedded in the larger tank. When water is poured into this tank so that it is approximately half full an airtight seal is produced. The idea for this tank originated from an ordinary acetylene generator.

Oxygen is admitted through the inlet *X*, thus causing the water to rise around the inner shell. When *X* is closed and *O* is opened, the oxygen in the tank flows out under the presssure of the column of water. One filling of the tank provides enough gas for four or five six-minute combustions. From the water tank the oxygen passes through two bottles, one acting as a safeguard against possible sucking back in the system, and the other containing a saturated solution of potassium hydroxide, which filters and dries the gas bubbling through it. The oxygen is subjected to final drying in a tower containing 20-mesh calcium chloride (*A* and *B*), 20-mesh sodium calcium hydrate (*C*) and concentrated sulphuric acid (*D*). After leaving the combustion tube (silicon) the gas passes through tubes containing: granulated zinc (*G*), 20-mesh calcium chloride (*E*), phosphoric anhydride (*H*) and 20-mesh calcium chloride (*F*). The zinc takes care of any sulphur gases which might have been formed in the evolution, the calcium chloride and phosphoric anhydride acting as drying agents before the gas enters the absorption bulb. Usually three special tubes are placed between the absorption bulb and the combustion tube; one for the calcium chloride, one for the zinc, and one for the phosphoric anhydride. This entails more costly and elaborate apparatus and requires more time for packing. The one simple tube containing all the necessary purifying agents in the minimum of space works excellently under heavy working conditions. Flemming or similar absorption bulbs packed in the usual way may be used as absorption media.

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Manipulation of the Method

A factor or a half factor weight (usually half factor is sufficient) of fine steel drillings is placed in a Johnson clay boat lined with RR alundum. These factor weights for carbon may be purchased, respectively, 2.7273 g. and 1.3636 g. and were used in order to eliminate reference to tables or calculation for the carbon percentage present. Gas is allowed to flow through the hot furnace for some time, to insure the removal of all CO_2 before the combustion is begun. A weighed absorption bulb is now fitted into place and the upper stopcock opened. The boat containing the sample is pushed into the middle of the combustion tube, the entrance stopper replaced and oxygen admitted. The lower stopcock of the bulb is now opened and the combustion is run for six minutes. At the end of this period the upper stopcock of the bulb is closed, then the lower stopcock, and the bulb is disconnected for weighing. The lower stopcock is momentarily opened to release the pressure in the bulb before weighing, the oxygen is now shut off and the boat containing the burned sample removed from the furnace. Any moisture or dust adhering to the bulb is carefully removed with a silk handerchief and the bulb is weighed against a tared bulb. The gain in weight is the percentage of carbon, since a factor weight was used. It is merely necessary to place the decimal point two places to the left in the case of a four-place weight.

With two furnaces in use, one balance for weighing samples and one for weighing the absorption bulbs, the writer frequently carried out seventy to seventy-five determinations in eight hours.

With low-carbon steels it is sometimes necesary to preheat the sample in order to obtain a perfect fusion. Two minutes' preheating is usually enough, and in such case the entire combustion should still occupy but the six minutes with a full factor weight and the five minutes with a half factor weight. This method gives accuracy to 0.01 per cent.

Artificial Iron Ore for Hydrogen Generation

An artificial iron ore has been developed by the Bureau of Standards for use in the steam-iron process of hydrogen generation. This material is made by impregnating a porous earthenware supporting body of approximate shape with iron nitrate and decomposing it to the oxide. Laboratory experiments on a limited scale indicate that this material is far superior to a natural iron ore for the purpose of producing hydrogen. The bureau is about to undertake the production of a sufficient amount of this material to permit of extensive tests in the hydrogen plant at Langley Field.

Injuries Caused by Emergencies

By Chesla C. Sherlock

MOST employers are familiar enough with the workmen's compensation laws to know that they are liable for the payment of compensation to injured workmen who receive their injuries through accidents arising "out of and in the course of" the employment.

Those employers who are operating under the common law theory of damages, and there are thousands of them, even in the states having compensation laws, know that they are not liable for accidental injuries caused to their workmen, unless the fault for the accident rests in the negligence of the employer in some particular. In spite of these provisions, there is one exception to the two rules mentioned above, which apply in all cases of accidental injury, whether the employer be operating under the compensation system or under the common law theory, and that is where emergencies arise which cause the injury to the workman.

A Concrete Illustration

Suppose, for the purposes of clearly illustrating this rule of law, that we take a concrete illustration embodying the essential features of the rule, which is common to the experience of employers generally. Let us suppose that the case arises in the factory of a chemical company, and that it arises through the agency of an explosion of chemicals.

A workman, John Doe by name, has been asked by his foreman to repair a leak in the gas tank of one of the company's automobiles. John removes the tank from the car, and carefully empties it of all the gasolene which it contains. He then takes the tank to a bench in one corner of the packing room and commences to heat a bit of solder with a blow torch.

In the office is one of his pals, a buddy he had known overseas, whose avowed duty it is, under the terms of his contract of employment, to take care of the office force. This man, Fred Jones by name, is not engaged in a hazardous occupation and is not covered under the terms of the workmen's compensation acts as they are generally understood. The employer does not even pay a premium on his risk.

As soon as John Doe, out in the packing room, applies his torch to the solder and moves it in close proximity to the hole in the gas tank, there is a terrific explosion, which not only kills John Doe, but scatters flames in every direction and severely burns another employee.

Fred Jones, who is working in the office, hears the explosion and sees his pal topple over. In his excitement he rushes through the office door in an effort to rescue him. But he is met by a scorching sheet of flame which drives him back. In his terror he realizes that the fire department must be summoned immediately or the entire plant will shortly be destroyed by the possible explosion of other chemicals stored in the packing room awaiting shipment.

Run Down Rushing to Fire Alarm Box

He turns and dashes into the office and out the front door. He does not summon the fire department by stopping in the office and calling Central as he might do, and probably should do. Instead, he remembers in that brief moment of terror that there is a fire-box alarm on the corner across the street, and he makes for that place.

Impelled by the sudden emergency which looms all-terrible in his mind, he does not look this way or that and before he reaches his destination he is struck by a delivery truck and seriously maimed and injured.

The cooler heads in the packing room, in the meantime, through the use of fire extinguishers close at hand, have put out the blaze and forestalled the threatened conflagration. John Doe's body is removed to an undertaking establishment and Fred Jones and the other employees are taken to the company hospital.

In the course of time, the employer sends in a claim for compensation not only for the workman who was injured through burns, but for Fred Jones as well. "I realize," he said, in making the claim to his insurance carrier, "that I have not paid a premium on the risk for Fred Jones, but I feel that he has a right to compensation under the law, and since by the terms of your policy you agree to hold me blameless for any and all claims of such nature and should have anticipated such a case, I have no hesitancy in claiming relief for Jones."

Insurance Company Denies Liability

A few days later an adjuster for the insurance company stepped off the train and made his way quietly to the chemical factory. He talked to a few workmen on the premises before he went to the office of the employer.

"I am authorized to make settlement in the cases caused by your recent explosion," he said, "but I am not prepared to accept liability in the case of Fred Jones. I have carefully investigated the circumstances surrounding his injury and I do not feel that he has a compensable claim."

"But," interrupted the employer, "how do you reach such a conclusion? His injury was clearly caused by the explosion. If he had not rushed across the street to turn in a fire alarm, he would never have been injured."

"That is true," replied the adjuster, "but when he went across the street he was outside the scope of his employment. His injury arose absolutely from causes entirely foreign to the duties of his employment, which were to manage this office force. And, besides, clerks and office people are not entitled to coverage under the terms of the workmen's compensation acts."

"Yes," agreed the employer, "but one of his duties was to do all that he could to preserve this business against loss. He was clearly acting for my welfare when he attempted to turn in a fire alarm and was clearly acting for my best interests. Technically, of course, he was not managing my office force then, but do you mean to say that the law is as narrow as all this? I thought that the compensation system prided itself on being free from technicalities."

The adjuster was firm in his position. "I can do nothing but refuse to pay compensation to Jones, until the Industrial Commission orders me to do so. Of course, if Jones wants to go to bat on this, he has the right and we will get the benefit of an official ruling on the case."

The employer's jaw snapped. "All right, I shall advise Jones to do that very thing, as soon as he is able, and I am going to give him all the legal assistance I have at my command!"

Judgment Against Insurance Company

In the course of time Fred Jones did bring an action against the insurance company for compensation and it was tried before an arbitration committee composed

of one Industrial Commissioner and two other arbitrators selected by the parties. The Commissioner wrote the following opinion, which was the unanimous decision of the committee:

"It is true that Fred Jones was technically outside the scope of his employment when he rushed across the street to send in a fire alarm. He was not even on the employer's premises and the accident that caused his injury did not arise out of the duties he was required by his employment to perform. But in this case a sudden emergency was presented upon which he acted, presumably with the idea of best promoting his employer's interests. And while in the course of that intention he suffered his loss and the impairment of his earning capacity.

"The emergency rule of law holds that an employee may be even guilty of an error of judgment, and still be entitled to relief from his employer for injuries sustained. Jones, it might properly be urged, should have used the telephone in his office to summon the aid of the fire department. He was, perhaps guilty of an error of judgment in dashing into the street, and thereby receiving injury to himself, but the law throws the mantle of protection over him in such circumstances, and this is true, whether we view the matter from the common law standpoint or from the compensation angle.

"As to the question of whether Jones should be denied compensation because he was technically not covered under the employer's policy of insurance, it is well settled that mere failure to include all risks in a policy does not absolve the parties from liability. Such a construction might properly be urged to defeat the whole system of compensation liability, and we feel that the best interests of the parties are promoted by awarding the claimant the relief he seeks."

It is not necessary to elaborate further, except to state that the emergency rule of law is a general rule and that it will apply to all employers, regardless of whether they are operating under one system or the other. It is one of the very few rules of law approved by the common law system which has been preserved in the compensation system of compensating injured workmen.

Wooden Posts for Plant Inclosures*

With the increasing necessity for proper protection of chemical and industrial plants by inclosing the property with wire or board fences the question frequently arises as to the right type of wooden posts in fence construction. The fact is, there is no choice between round or split posts if the amount of heartwood is the same in both. But if the percentage of sapwood is increased by splitting, the split posts will be less durable, and if the percentage of heartwood is increased, it will be more durable than a round one. Posts of spruce, hemlock or any of the true firs are exceptions to this rule, because their heartwood and sapwood are equally durable.

When posts are to be treated with creosote or other preservative, a round post is preferable to a split post, because of the comparative ease with which the sapwood can be treated. The heart faces on split posts do not, as a rule, absorb preservative well. Split red-oak posts will take treatment, because the wood is very porous, but the heart faces of split posts of many other species, notably white oak, red gum and Douglas fir, resist the penetration of preservative, even under heavy pressure.

*Forest Products Laboratory *Technical Notes.*

Progress of Belgian Chemical Industry

The Belgian chemical industry is composed of a Federation des Industries Chimiques de Belgique, which is subdivided into a series of fifteen associations, says a recent consular report. The information for certain associations is missing or incomplete, but the following figures relate to the production of those for which figures could be obtained by the Ministry of Economic Affairs:

Products	Metric Tons	
Soda, potash and derivatives:	1913	1920
Carbonate of soda	31,234	31,000
Caustic soda	3,261	2,418
Chloride of lime	7,444	3,970
Chloride of calcium	6,025	2,850
Potash and derivatives	47,964	40,229
Acids, minerals and derivatives:		
Sulphuric acid	600,000	400,000
Nitric acid	10,000	7,500
Hydrochloric acid	22,500	27,000
Sulphate of soda	25,000	40,000
Superphosphate of lime	465,000	220,000
Wood products for distillation, cubic meters	46,000	21,000
Products of coal distillation:		
Alkali	1,500	894
Anhydrous ammonia	40	62
Sulphate of ammonia	22,696	9,048
Benzene, 90 per cent	5,216	4,194
Coal tar	37,337	25,872
Naphthalene	5,593	4,702
Creosote oil	8,705	5,543
Tar	47,106	28,304
Light oils	6,277	1,785
Powders and explosives	3,500	2,200

The present production of artificial silk is about 70 per cent of what it was before the war.

Gas-Fired Crucible Furnaces

Before the Sheffield Society of Metallurgists and Metallurgical Chemists, on April 19, F. M. Parkin, of Hobson, Houghton & Co., advocated the use of gas-fired furnaces for melting crucible steel as being superior in all respects to the coke-fired furnaces which have been employed ever since the crucible process was invented by Huntsman. There are a number of gas-fired crucible furnaces in Sheffield, but the newer method is in its infancy. Mr. Parkin said that gas-melting was cheaper than coke fuel, the operation was less arduous for the workmen, and the product—at any rate as regards composition—was superior to the material made with coke. Speaking from an experience of a considerable number of years with the Harvey-Siemens regenerative furnace, he stated that he had produced hundreds of tons of steel every year, which was sold in competition with coke-made steel, and the results had been highly satisfactory. The steel was better than the steel which was made by the older fuel.

New German Refractory Product

A new method of converting ordinary bricks into refractory firebrick has been perfected in Germany, consisting of a coating comprising a mixture of 75 per cent carborundum and 25 per cent sodium silicate. The mixture is applied to the bricks when they are thoroughly dried, and the coating sets and thoroughly dries in twenty-four hours, being slowly heated and burned in. This coating averages about one-fiftieth of an inch in thickness, and the adherent glassy veneer of carborundum gives remarkable resistance to any mechanical injury; it has the ability to withstand very high temperatures and affords complete protection against the chemical action of flames. It is said that sudden changes of temperature do not have any effect upon it. This coating has been used successfully as a lining for gas retorts as well as for the outside surface, and a paste of equal parts of carborundum and clay is used for repairs when cracks occur.

Suggestions for Calibrating Base Metal Thermocouples by the Freezing Point Method

By Kirtland Marsh*

When calibrating thermocouples by the freezing point method, it is essential that the metals used be pure and maintained pure. Pure tin, zinc, aluminum and copper can be readily obtained from the Bureau of Standards for this purpose, but care must be exercised in using them to guard against contamination. This is realized by inclosing the thermocouple to be calibrated in a sheath to protect it from the molten metal. The sheath also prevents short-circuiting the couple at the surface of the metal. Hard glass tubes can be used for tin and zinc, but in aluminum these are unsatisfactory, and they cannot be used in copper. An iron tube can be used in any of these metals satisfactorily if steps are taken to prevent the contamination of the metal by the iron. This can be prevented in the following manner:

Prepare a mixture of one part by volume of graphite and two parts water; flake graphite will not mix readily with the water, but finely powdered graphite or ordinary plumbago, such as is used in foundries for facing, is satisfactory. Heat the sheath to about 900 deg. F., dip in the above mixture and withdraw quickly in order that there will be enough heat left in the sheath to dry the coating of graphite. The mixture should be thoroughly stirred before being used, because the graphite or plumbago will settle to the bottom of the container. A suitable container can be made of a piece of 4-in. iron pipe capped on one end and long enough to extend about 12 in. above the surface of the mixture to prevent spattering.

The sheath, after having been dipped and a smooth dry coating of graphite obtained, can be immersed in the molten metal without fear of contaminating it. After the sheath has been removed, any clinging metal and dross can be readily removed and the same sheath safely used in some other metal.

The only precaution necessary is to remove any loose oxide scale from the sheath before it is dipped and immersed in the metal; if this is not done, some of the scale may chip off and fall into the metal and thus render it impure and alter the freezing point.

When copper is used the furnace temperature is high enough to burn off the coating of graphite and in this case a second coating of lime can be used to protect the graphite. A suitable lime wash can be made of one part by volume of slaked lime and one part water. Heat the sheath to 900-1,000 deg. F., dip in the graphite wash, quickly remove and allow to dry thoroughly and then repeat in the lime wash. Both coatings will generally dry thoroughly without reheating.

Thermocouples of the pencil type, consisting of an insulated wire element welded at one end to a tubular element inclosing it, can be calibrated without a sheath if they are given a protective coating of graphite.

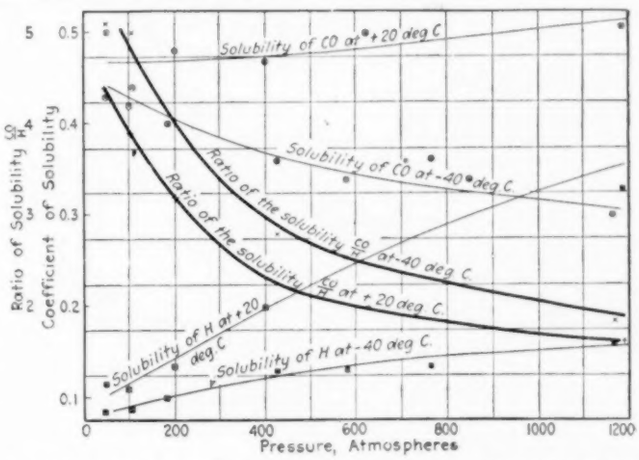
The chief advantages of these washes in calibrating thermocouples are as follows: metal sheaths which are much stronger and more rugged than refractory sheaths can be used; the molten metal is protected from contamination; one sheath can be used in all the metals because it can be thoroughly cleaned, and couples of the pencil type can be calibrated without any sheath, under which conditions the couple is much more sensitive to temperature changes and the calibration rendered more reliable, particularly when only a little metal is used.

*Aluminum Company of America, New Kensington, Pa.

Synopsis of Recent Chemical & Metallurgical Literature

Production of Hydrogen for the Manufacture of Synthetic Ammonia by the Hyperpressure Process.—In a note presented before the French Academy of Sciences, Feb. 21, 1921, Georges Claude stated that the commercial success of the hyperpressure process for the manufacture of synthetic ammonia depends on the economical production of hydrogen.* In another note of April 4, 1921 (*Comptes rendus*, April 18, 1921, pp. 974-977), he describes his experimental work for the production of practically pure hydrogen by separating it from its mixtures, such as water gas and coal gas. This separation is easily realized by the application of the principle of the insolubility of hydrogen and the solubility of the other gases of the mixture in ordinary ether.

The mixture, compressed to a given pressure, is passed through the solvent at a very low temperature when all the



SOLUBILITY OF HYDROGEN AND CARBON MONOXIDE IN ORDINARY ETHER

gases but hydrogen are dissolved in the ether. The solvent with the gases in solution is drained off, and when expanding to atmospheric pressures the dissolved gases escape, leaving the solvent ready for re-use.

The difficulty encountered in the use of this process is that the hydrogen obtained is somewhat contaminated with carbon monoxide; but a series of tests has led to the practical means of how to reduce the CO content to a minimum. This is best shown in the accompanying figure giving the solubilities of hydrogen and the carbon monoxide in ordinary ether at +20 and —40 deg. C. for pressures up to 1,600 atmospheres. By working at a low temperature, —40 deg. C., and at a pressure of about 100 atmospheres it is possible to obtain hydrogen containing less than 0.002 part CO.

Predicting Strength of Rolled Steel.—William R. Webster is to read a paper before the Wilkes-Barré meeting of the American Institute of Mining and Metallurgical Engineers, reopening a subject which was much discussed during the early '90s. Since then Campbell,[1] Cunningham,[2] Stead[3] and McWilliam[4] have proposed formulas for the relation between chemical composition and strength. It was early recognized that differences in amount of reduction during rolling would account for 6,000 to 10,000 lb. per sq.in. tensile strength.

*See Chem. & Met. Eng., April 20, 1921, p. 706.

[1]"Manufacture and Properties of Iron and Steel."

[2]*Trans.*, Am. Soc. Civil Eng., vol. 38, p. 78 (1897).

[3]*J. Iron and Steel Inst.*, vol. 44, p. 5 (1916).

[4]*J. Iron and Steel Inst.*, 1918, II, McWilliam's formula for ultimate strength normalized 1 in. bars of basic open-hearth steel is 38,000 + [800 + 4(C — 20)] C + 120 Si + [100 + 2(C — 20)] Mn + 1,000 P.

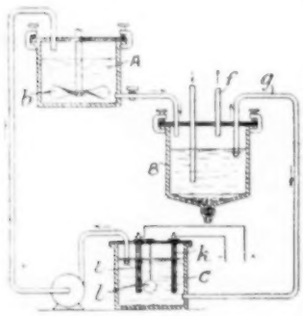
Finishing temperature also had an important influence; in fact, several steel works have found it useful to construct tables of their own to include the effects of all the conditions existing at that particular place. One such table for basic open-hearth steel is quoted, and Mr. Webster finds that by starting with 50,145 lb. per sq.in. for a 0.10 per cent C, 0.34 per cent Mn steel, the results would be closely approximated by giving an increase of 830 lb. for each point carbon and 170 lb. for each point manganese. "When phosphorus is greater than 0.02 the figures should be increased at the rate of 1,000 lb. for each 0.02 per cent that the phosphorus exceeds 0.01 per cent."

Recent Chemical & Metallurgical Patents

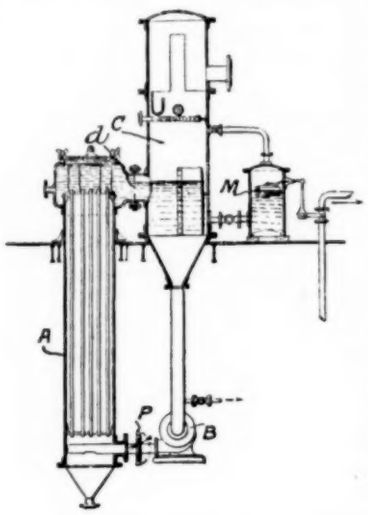
British Patents

For complete specifications of any British patent apply to the Superintendent British Patent Office, Southampton Buildings, Chancery Lane, London, England.

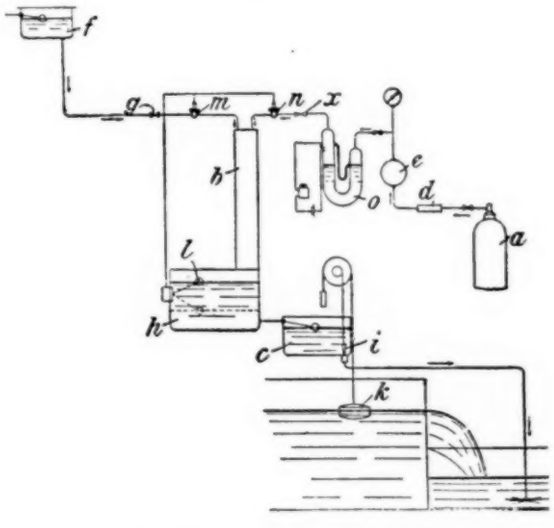
Refining Platinum.—In the separation of platinum from other metals, there is obtained a solution containing gold and palladium, which are then precipitated, leaving a pure platinum solution from which the metal is electrodeposited. The precipitation of gold and palladium may be effected by means of hydrogen previously treated with ultra-violet light, for instance by passing the gas through a helical silica tube surrounding a silica mercury-vapor lamp. If a plate of gold or palladium is placed in the solution, a voltaic couple is stated to be formed with the hydrogen. In obtaining the solution of platinum, gold and palladium there may be employed broken ingots of impure platinum or sludges resulting from electrolytic treatment of impure gold anodes in nitric acid solution, the silver being deposited on the cathode and platinum, iridium, palladium, gold and lead precipitated. The impure metal or sludge may be treated with diluted aqua regia at 70 deg. C. in a closed vessel *A* provided with a stirrer *b*. Only the platinum, palladium and gold dissolve. An alternative method of obtaining such a solution consists in treating an impure gold anode in acid auric chloride solution or aqua regia, silver, iridium, rhodium, ruthenium, etc., remaining undissolved. A part of the gold may then be deposited electrolytically, say in the same cell, but the solution must be removed from the cell when it contains 3 per cent of gold, 6 per cent of platinum and 0.5 per cent of palladium. Treatment with the hydrogen is effected in a closed vessel *B*, excess of gas escaping by a pipe *f*, and the solution being removed by a pipe *g* extending downward through one-third of the height of the vessel. The electrolytic vat *C* for the deposition of platinum is provided with a tight cover and with electrodes *k*, *i* of pure retort carbon. A current density of 4.8-9 amperes per sq.dm. is suitable. Removal of the spongy platinum may be facilitated by slightly paraffining the cathode. If the anode is exposed to ultra-violet light, the chlorine is enabled to act on water, regenerating hydrochloric acid and producing oxygen, which either acts on nitrogen oxides present in the electrolyte to regenerate most of the nitric acid for re-use, or escapes with the hydrochloric acid to the first electrolytic cell where it assists dissolution of the gold anode. The source of ultra-violet light may be a silica mercury-vapor lamp *l*, placed either between the electrodes and near the anode, or outside a window in the wall of the cell. (Br. Pat. 157,785; not yet accepted; F. SLATINEANU, Cressy-Onex, near Geneva. April 6, 1921.)



Evaporating Liquids.—In an evaporating apparatus in which liquid is heated by circulation through a tubular heating apparatus *A* and is evaporated in a separate chamber *C* from which the unevaporated liquid is returned to the heater, the formation of vapor in the heater is prevented by increasing the pressure therein by providing a restricted outlet *d* between the heater *A* and the vessel *C* and by inserting a pump *B* in the pipe which returns the liquid to the heater. The pressure is regulated by a valve *P*. A float regulator *M* serves to regulate the feed of liquid to the evaporator. To increase the transmission of heat in the heater *A*, the speed of flow of the liquid in the tubes is increased by the pump *B*, the tubes are placed closer together, and the steam is circulated repeatedly over the tubes. In evaporating salt solution, the conical base of the chamber *C* is connected to a vessel adapted to receive the deposited crystals and to discharge them by admission of compressed air. In evaporating liquids such as milk, fruit juice, gelatine solution, etc., the heater *A* is heated by circulation of hot water which is heated in a second tubular heat-exchanger heated by steam. (Br. Pat. 158,569; BARBET ET FILS ET CIE., Paris. April 20, 1921.)



Sterilizing Liquids.—In sterilizing water or other liquid by addition of chlorine or other gas, water and chlorine are passed in regulated streams to an absorber *b*, and the chlorinated water which collects in a vessel *h* is supplied to the main flow of water in proportionate quantities. Chlorine is passed from a reservoir *a* through a filter *d*, a reducing valve *e*, a metering device *o* and a regulating valve *x* to the absorber *b*, and water is passed from a tank *f* through a valve *g*. The chlorinated water passes from the vessel *h* to a vessel *c* through a float valve and is fed through a tapered valve *i* controlled by a float *k* immersed in the main flow of water passing over a weir. The flow of chlorine and water to the absorber may be regulated by diaphragm valves *m*, *n* operated by a float *l* in the vessel *h*. The metering device *o* may be arranged to record the amount of chlorine that passes through it. (Br. Pat. 158,578; W. PATERSON, London. April 20, 1921.)



Current Events
in the Chemical and Metallurgical Industries

American Engineering Council Receives Report on Waste Elimination

At the regular bimonthly meeting of the executive committee of American Engineering Council in St. Louis on June 3, the Committee on Elimination of Waste in Industry made a report of the investigations which it has been conducting for the past six months. The outstanding feature of the report was the responsibility placed upon management for 50 per cent of the wastes of industry, while less than 25 per cent was laid at the door of labor. The investigation revealed a margin of unemployment of more than a million men, idle equipment valued at billions of dollars, and a waste of time, energy and money in other ways amounting to millions annually.

The full report of the committee, which was not adopted by Council, but which is to be published under its authority as a committee report and signed by the committee, comprises 125,000 words and deals with the deep-seated causes of waste apart from the world-wide waste and extravagance caused by the war. It discloses loss and waste from interruption of production, low production, restriction of production, and lost production.

Wastes attributable to faulty management are characterized as follows:

"The average method of management is far behind standards which have demonstrated their practical value; billions of dollars are tied up in idle equipment, and there is a large additional waste through maintenance and depreciation charges; manipulations in raw material result in serious losses; an evil in some instances is the practice of cancellations and returns; high labor turnover is a rough index of one of the commonest wastes in industry; the waste of time and energy and money through duplication of estimates and bids in the building trade runs into millions every year; quantity figuring by all bidders is a duplication of effort and a source of waste in construction work."

Both employer and employee are charged with restricting production, the former by limiting the total output of an industry and the latter by limiting the rate of production of the individual. Preventable diseases and industrial accidents account for an economic loss of over three billion dollars per annum.

In order to eliminate much of the waste the committee recommends a program of governmental assistance involving the establishment of a national industrial information service, a national statistical service, a national health policy, a nation-wide program of industrial standardization and a revision of such federal laws as interfere with stabilization of industry through trade associations and similar organizations.

Numerous other committees made reports at this meeting of Council, but no important action was taken. The next meeting probably will be held in September, at which time it is likely that a president will be elected to succeed Mr. Hoover. The Council voted to send out nomination blanks.

Three new organizations were elected to membership in the Federated American Engineering Societies. These are: Jamestown Engineering Society, Vermont Society of Engineers and Technology Club of Syracuse.

Exercises at Edgewood Arsenal

Special exercises were held at Edgewood Arsenal on June 4 in commemoration of the anniversary of the establishment of the Chemical Warfare Service as an integral subdivision of the Army. In addition to addresses in which the accomplishments of the year were reviewed, there was a minstrel show, moving pictures and a dance.

A. C. Fieldner Becomes Superintendent of Pittsburgh Station, Bureau of Mines

The important post of superintendent of the Pittsburgh station of the Bureau of Mines has been filled by the appointment of Arno C. Fieldner. Mr. Fieldner has been the acting superintendent of the station since June, 1920. An administrative assistant will be employed, so that Mr. Fieldner may carry on the greater part of his research work. He will continue to discharge the duties of supervising chemist. As superintendent, Mr. Fieldner will receive a salary of $5,000.

While Mr. Fieldner has demonstrated that he has unusual executive ability, he has been disinclined to accept an administrative position. Former Director Cottrell, of the Bureau of Mines, and Director Bain each has been anxious that Mr. Fieldner continue uninterruptedly on his research work. A determined effort has been made to secure a properly qualified person, other than Mr. Fieldner, for the position. The difficulty is, however, that such engineers are unwilling, or are not in a position, to make the financial sacrifice necessary with the Government's scale of salaries.

Experimental work calling for nearly $400,000 a year is being conducted at the Pittsburgh station.

Mr. Fieldner formerly was a member of the U. S. Geological Survey. He went with the Bureau of Mines at the time its work was separated from that of the Geological Survey. During the war he was transferred to the Chemical Warfare Service, where he attained the rank of major. On June 13, 1919, he was re-transferred to the bureau and was made supervising chemist at Pittsburgh. Since the promotion of E. A. Holbrook to be assistant director of the bureau Mr. Fieldner has acted as superintendent.

Patent Amendment Proposed

In the interest of the national defense and to prevent unwarranted advantages to foreign inventors, Senator Stanley of Kentucky has proposed an amendment to the Revised Statutes providing that any patents issued to foreigners must be put in operation and production in reasonable quantities begun within the continental limits of the United States within two years. Failure to comply with that provision entitles the United States to issue a license which will permit use of the patent.

The legislation, Senator Stanley states, is intended to prevent such a situation as arose at the outbreak of the war when the United States was cut off from supplies of dyes which were made only in Germany. German interests had American patents covering more than 1,000 coal-tar products. Had these interests been required to manufacture their products in the United States American industries depending on them would not have been paralyzed. Senator Stanley points out that practically every other nation has a law requiring compulsory production, within the country, of patented articles taken out by foreigners.

American Ceramic Society Announces Summer Meeting

The American Ceramic Society's summer meeting will be held at Canton, Alliance, Sebring and East Liverpool, Ohio, July 25 to 27 inclusive, with headquarters at the Hotel Courtland, Canton, Ohio.

Among the plants visited in Canton will be the Deuber Watch Case Co. On the evening of July 25 a banquet will be held at the Canton Country Club. On Tuesday the members will visit ceramic plants in Alliance, closing the day with a dinner party and smoker at Myers Lake. Wednesday, the 27th, will be devoted to visiting plants in the East Liverpool district.

Research Council Chemical Division Officers Elected

Dr. F. G. Cottrell has been re-elected chairman of the Division of Chemistry and Chemical Technology of the National Research Council for the year beginning July 1. Julius Stieglitz was elected vice-chairman. The executive committee, in addition to Drs. Cottrell and Stieglitz, will be composed of W. D. Bancroft, R. B. Moore, W. F. Hillebrand and C. G. Fink.

Members at large of the Division of Chemistry and Chemical Technology, elected for three years, are Treat B. Johnson, New Haven, Conn., and R. B. Moore, Washington, D. C.

Representatives of constituent societies have been selected as follows:

American Chemical Society—C. E. Franklin, Stanford University, California; John Johnston, Yale University, New Haven, and J. E. Teeple, New York City.

American Ceramic Society—Albert V. Bleininger, Bureau of Standards, Washington.

Dr. Cottrell Goes to Europe

Dr. F. G. Cottrell, chairman of the division of chemistry and chemical technology of the National Research Council, sailed June 11 for Europe to make a survey of the applications being made of helium in European countries. He also will make a special study of oxygen separation and concentration. In this work he is representing the U. S. Bureau of Mines as well as the Research Council.

While in Europe Dr. Cottrell will attend the meeting of the International Union of Pure and Applied Chemistry, which is to be held in Brussels June 27. Other delegates selected by the National Research Council to attend the Brussels meeting are E. S. Chapin, Frederick G. Keyes, Collin McCall, H. S. Taylor and James B. Conant.

Chicago Meeting of the Refrigerating Engineers

The American Society of Refrigerating Engineers held its eighth Western meeting at the Hotel Drake, Chicago, May 25 to 27.

Business Session

One of the most important items that this association has under advisement is the preparation of a mechanical refrigeration code, a committee of the society working in co-operation with the American Engineering Standards Committee. A tentative code was presented to all the members present and considerable discussion followed, several exceptions being taken particularly to the pressures listed for ethyl chloride, sulphur dioxide and methyl chloride, which were said to be too high compared with the corresponding pressures given for ammonia. Other members took exception to the fixed specifications on electrical equipment as regards its being isolated from the refrigerating equipment in the power house. It was further agreed that the lower limit of three tons as the size of plant requiring a licensed engineer was an unreasonably low figure, which should be raised to twenty or thirty tons.

In the discussion on the Bureau of Standards work with anhydrous ammonia it was decided that the two fellowships which are maintained by the society at the expense of about $6,000 per year should be continued for the coming year. By 1923 the work on the anhydrous ammonia tables will be completed and some work started on CO_2. Furthermore, it is expected that the Government will appropriate enough money to continue this work indefinitely for the benefit of the industry.

Multiple Effect Compression

H. C. White of the Consumers Co., Chicago, delivered a paper on "Multiple Effect Compression," where a method is employed consisting of first filling the compressor cylinder with low-pressure gas and then near the end of the stroke switching over the valves and admitting gas at higher pressure to compress the charge and fill the cylinder with the denser gas. Machines of the Consumers Co. have been equipped with these Voorhees devices, resulting in considerable gain in economy.

Data were given on a single-acting compressor with a condenser pressure of 185 lb. and a suction pressure of first 20-lb. gage and then 35-lb. gage. In the first case it was necessary to compress 4.17 cu.ft. of gas per ton of refrigeration with a compression horsepower of 1.336, while in the second case 2.84 cu.ft. was compressed with a horsepower 0.98, showing that 47.5 per cent more capacity was obtained and 26.5 per cent less power was used per ton of refrigeration. For each pound increase in suction pressure the saving was placed at 1.76 per cent.

Brine Spray Refrigeration

S. C. Bloom, in discussing "Brine Spray Refrigeration," compared a new type of nozzle which gave a hollow cone-shaped spray with the earlier inefficient devices giving a coarse flat spray. One of the earlier methods was to use a plugged nipple discharging against a plate, or an adjustable nozzle which the operator could change at will. Pressure ranged from 20 to 70 lb., although 25 lb. would have been sufficient in most cases. Spaces between nozzles in the older types varied from 12 to 48 in. according to the notion of the designer and mains were further connected in parallel so that reduction of pressure on one would affect all. Brine temperatures employed ranged from 8 to 20 deg. F. and the height from deck to ceiling averaged from 6 to 8 ft. It was further commonly thought that the stronger the brine solution the better would be the results.

Improvements in the deck system of spraying had been sought by the author and applied quite extensively in the Chicago plants of Armour & Co. A weak brine solution was used and the problem of obtaining better circulation and more rapid cooling was undertaken. The nozzles formed a spray of a hollow cone shape and were so spaced that the cones of spray intermixed and filled the entire space of the cooler loft. Experiments showed the most suitable pressure was 7½ lb. Gravity tanks were arranged above the nozzles to prevent variation in pressure and this, coupled with non-adjustable nozzles, made a system practically fool-proof. Experiments showed that the latter type of system was much more desirable. In modern installations more brine surface is presented to the air and more rapid circulation obtained through the brine and proper spacing of nozzles, all of which makes better concentration of ammonia at the power house.

Spray Cooling Systems

O. J. West read a paper on "Spray Cooling Systems," which brought out the great increase in cooling capacity obtained by the use of sprays as compared with a basin or pond without sprays. The proper use of piping arrangement was suggested, operating pressures were given and nozzles described. The spray system is coming into greater use, there now being over 2,000 installations in the United States.

Fundamental Constants

E. F. Mueller, of the U. S. Bureau of Standards, presented a report on the progress in the determination of the fundamental constants of refrigeration engineering, including a set of standard anhydrous ammonia tables. These tables may be obtained by addressing the Bureau of Standards at Washington, D. C., or securing a copy of the January issue of the *Journal* of the American Society of Refrigeration Engineers published at 154 Nassau St., New York.

Refrigeration in Rubber Manufacture

"Refrigeration in the Manufacture of Rubber" was given by J. H. Vance. Since the raw rubber arrives at the factory full of dirt, bark and wood chips, it is first necessary to wash it. This process is carried on by passing the material through cast-iron rolls made with chilled surfaces and so corrugated that a crushing and shearing action takes place as the rubber passes through. From these rolls it enters the washers and sheeters, whence it emerges in the form of a thin irregular sheet. The wash water at this point must be below 76 deg. F. to prevent tackiness, and often refrigerated water must be used to maintain this temperature.

After the rubber is thoroughly washed it is passed into drying rooms or vacuum driers and passes through hollow

rolls, where it is masticated. These rolls operate in pairs with a speed ratio of 1½ to 1 revolution. From the drying room the material is passed to the mixing mill, which consists of sets of rolls for working the rubber. Each set consists of two hollow cast-iron cylinders with smooth surfaces operating at a speed of 1 to 1½ revolution ratio. This operation causes a grinding of the rubber at the same time the additional compounds are being mixed in. The friction at this point generates so much heat that it is absolutely essential to use refrigerated water to keep these rolls at the proper temperatures. In a typical plant where 5,000 gal. of water per minute was used, figures were taken to determine the exact amount of refrigeration required.

The mixing heat on rolls varies widely but must be kept below 176 deg. F. to prevent scorching of the rubber. In this particular plant in question the water temperature on entering the inside of the hollow roll was 58 deg. F. and the return water was 64 deg. F. In making the calculations for refrigeration count was taken of the friction load, driving load, thickness of metal and other factors. It developed that 788 hp. was consumed in the operation, producing enough heat to require 167 tons of refrigeration. In carrying the figures down it developed that one-sixth of a ton of refrigeration was required per lineal inch of roll face to maintain the necessary temperature.

Other papers presented were "Automatic Appliances for Refrigerating Machines," "Modern Air Compressor Practice and Testing," "Water Treatment for Raw Ice" and "Egg Shell Sterilization for Cold Storage." The convention closed with an informal dinner at the Hotel Drake and various plant trips in the vicinity of Chicago.

Program Arranged for New Jersey Clay Workers Meeting

In connection with the program for the summer meeting of the New Jersey Clay Workers Association and Eastern Section of the American Ceramic Society, to be held at Trenton, N. J., on June 17, Prof. George H. Brown, director of the Department of Ceramics, Rutgers College, New Brunswick, and secretary of the association, has arranged for a number of interesting papers and addresses. Among these will be a technical paper on the subject of "Hollow Building Tile," by Walter A. Hull, United States Bureau of Standards, Washington, D. C., and a lecture by Prof. A. S. Watts, Ohio State University, Columbus, on "Factory Preparation and Burning of Whiteware Bodies." An address will be made by William Burgess of the United States Potters' Association. At both morning and afternoon sessions there will be a discussion of practical problems pertaining to the ceramic industry, such as kilns, kiln firing, saggers, etc. It is proposed to arrange a trip to a number of representative local potteries.

American Farm Bureau Federation Report on Muscle Shoals

The executive committee of the American Farm Bureau Federation has approved unanimously the report prepared by the special committee appointed to investigate the entire Muscle Shoals project. After thorough study the committee recommends that the Wilson Dam be completed by the Government without further delay and that the nitrate plants be placed under the direction of a Government owned corporation which may, at its discretion, operate the plants or maintain them ready for operation, but with strict regulations as to prices to be obtained for commodities in which the products of these plants are used.

Will Discuss Plastering Code

Chapter 3 of the proposed national plastering code will be discussed at a conference at the Bureau of Standards June 20. This chapter is devoted to plaster materials. Chapter 1 of the proposed code has been completed. It deals with masonry backing for plaster. Chapter 2 deals with lath backing and is nearly completed. Chapter 4, dealing with mixing and application of plaster, was recently started. Chapters to be written later include "Properties of Finished Materials," "Methods of Testing Finished Plaster" and "Patching and Decorating."

Chicago Section of American Ceramic Society Holds Spring Meeting

Members of the Chicago Section, American Ceramic Society, met at an informal dinner on May 23 for the spring business session and presentation of informal papers.

Reflector Enamels

Cullen W. Parmelee abstracted a paper on the development of a reflector enamel, being the thesis of William R. Morgan and A. H. Charles of the University of Illinois. Tests were run to determine the combined effect of cobalt and nickel in ground coat for sheet steel enamel. Comparisons were made of color and texture and impact tests were carried out on the pieces. It was found that 900 deg. C. was the most favorable temperature to which the enamel should be heated. The toughness of the enamel decreased as the temperature was increased above this point. The best mixture of the two oxides was determined as 1 per cent nickel oxide and 1 per cent cobalt oxide. It was concluded that the presence of nickel is conducive to uniform color and that the amount of cobalt oxide necessary is in excess of that used in general practice. An increase in the percentage of total color oxide content decreases pinholing at the proper maturing temperature. Cobalt oxide is valuable as an indicator of maturity.

Further experiments were made with chromium oxide, spinel and tin oxide in enamel. The tests showed that tin oxide has the highest reflecting power, spinel the next highest and zirconia the least amount. The practical limit for the quantity of tin oxide added is 10 per cent. Spinel is interesting as a substitute for tin oxide using about 8 per cent. It is, however, about 10 per cent less efficient than tin oxide.

Pyrometry

G. V. Nightingale and F. C. Baker conducted an instructive discussion on pyrometry, with particular reference to the types used in industrial practice. The recording pyrometer is an accurate check on the clay burner. The potentiometer is the most accurate type of instrument used but it is difficult to get the operators to give it the proper care.

Business Meeting

A motion was carried after considerable discussion to have a committee appointed for meeting with a similar committee from the Illinois Clay Manufacturers Association, such joint committee to consider the amalgamation of the Chicago Section of the American Ceramic Society with the Illinois Clay Workers Association.

Motion was carried to place the power in the hands of the executive committee of the local section to appoint four members for service on the advisory board of the University of Illinois.

Chester H. Jones was nominated to serve on the committee of the national society for selecting American Ceramic Society national officers for the coming year.

Research Work on Electrodeposition

During the past month a member of the Bureau of Standards staff attended meetings of the American Electrochemical Society in the interests of research work on electrodeposition. A great deal of interest was shown in the proposed program and plans were made for the formation of a division of the society to be concerned wholly with this kind of work. If such a division is organized, it will be a distinct advantage in bringing together persons interested in this field and thereby stimulating research work along electrochemical lines.

Letters have been sent out by the National Research Council to about 200 representative manufacturers in whose plants electroplating is an essential process. The purpose of these letters is to inquire whether they would be willing to furnish financial support toward research work on electrodeposition. If such support is received, it is expected that the funds will be expended for research work conducted at the Bureau of Standards under the general supervision of a representative advisory board.

Industrial Alcohol Makers Not Satisfied

Manufacturers of industrial alcohol are far from satisfied with Representative Volstead's bill, supplementing the national prohibition act. In its final form, as reported favorably to the House of Representatives, language was added specifically stating that nothing in the bill is to authorize the prohibition commissioner to limit the quantity of alcohol that may be manufactured.

The parts of the bill to which most objection is taken are sections 3 and 4. As presented to the House, these sections read as follows:

SEC. 3. The commissioner shall only grant the permits that are necessary to supply the actual needs for non-beverage purposes and shall limit the supply and use of all liquor save denatured alcohol and denatured rum unfit for internal use to such non-beverage needs. *But this provision shall not authorize the commissioner to limit the quantity of alcohol that may be manufactured, nor shall it be taken to repeal the right of the applicant for a review of the decision of the commissioner in refusing a permit by a court of equity as provided in the national prohibition act.* If the commissioner shall find that any article enumerated in subdivisions b, c, d, or e of section 4 of title 2 of the national prohibition act is being purchased for use as a beverage, or for intoxicating beverage purposes, he may require a change of formula of such article or cancel the permit for the manufacture of such article unless it is made clearly to appear to the commissioner that such use can only occur in rare or exceptional instances.

No intoxicating liquor other than alcohol shall be used in the manufacture of any article enumerated in subdivisions b, c, d, and e of section 4, title 2 of the national prohibition act unless it shall clearly appear to the satisfaction of the commissioner that the use of intoxicating liquor other than alcohol is essential as a component part of such article.

SEC. 4. Not less than twenty days before an annual permit is issued for the sale of any liquor or the manufacture of any liquor or any article enumerated in subdivisions b, c, d, and e of section 4, title 2, of the national prohibition act, the application therefor shall be filed with the commissioner and made a public record, and notice thereof shall be served by registered mail on the Attorney General and the commissioner may require such notice to be publicly posted at the applicant's place of business as regulations may prescribe. Any federal or state officer or any person authorized thereto by any such officer may oppose any such application.

Despite the objections raised to dual control by the prohibition commissioner and the Attorney General, no change was made in that part of the original bill. The committee did accede to the objections voiced against the requirement that a part of the component materials must be added to alcohol at the distilleries. Users of industrial alcohol also objected to the requirement that the permit be publicly posted at the applicant's place of business. It was argued that this requirement places the industrial users of alcohol on much the same footing as saloons formerly were.

Secretary Hoover on Trade Associations

The attitude of the federal administration toward the trade organizations of the various industries has been made clear by recent announcements by the Secretary of Commerce and by the Attorney General. The Attorney General has given notice that he will push a test case against one of the open-price associations. There will be no dragnet thrown over all the associations and there will be no wholesale indictments, Attorney General Daugherty declared. Secretary Hoover authorized the following statement:

The relation of trade associations and trade institutes to the anti-trust laws have been discussed at great length in the Administration. Of the many thousands of such organizations there are a small minority who have degenerated into ways that make for restraint of trade.

All are agreed that the purposes and actions of the vast majority of national associations are a constructive contribution of public welfare. Their activity in promotion of better business practices, advancement of technical processes, simplification of production standardization of quality, extension of foreign trade, commercial arbitration, etc., makes for more efficient industry and business. Many of them collect information as to the production, stocks of raw and other material, percentage of industry in active operation, and total orders in hand, all of which when available to the public contribute both to stability and the increasing efficiency of industry and to the protection both of the smaller manufacturer and the consumer. The Department of Commerce wishes to cooperate and assist with all of this sort of effort.

A smaller number of such associations have been engaged in the collection of data on the prices for the exclusive use of their members. Some of these associations have been charged with delimiting areas of commodity distribution among their members and other misuse of information. Whether these latter practices constitute a violation of the national anti-trust laws must be determined by the courts, and this the Attorney General is vigorously proceeding to find out.

All this raises anew the question of the authority of the Federal Trade Commission. The original conception of the commission was that it should, among other things, advise business men as to what constituted a violation of the restraint of trade laws, but these powers were struck out in the course of original legislation. It seems to me that the seven years' experience with the commission should now enable a reconsideration of its powers with a view to giving it a more constructive function, subject say to review by the Attorney General, by which it could remove the uncertainties from the mind of business men as to the line between the field of co-operation for promotion of production and trade in public interest and the field of practices against public interest. There is nothing so destructive of business as uncertainty, and business has inherently enough uncertainty to deal with, without this one.

Hercules Powder Co. Acquires Aetna Explosives Co., Inc.

Rumors of the proposed purchase of the Aetna Explosives Co., Inc., by the Hercules Powder Co. received definite confirmation last week, when the Aetna stockholders sanctioned the sale of its properties, assets and business. This marks the culmination of a transaction that has interested financial and business circles for the past two years, and which in addition to being a deal of considerable moment also presents an unusual legal aspect.

Although it has been understood practically since the close of the war that negotiations were under way between these two manufacturers, it was not until the petition of the Hercules company for permission to purchase the Aetna company had been acted on favorably by the Circuit Court of Appeals, sitting as the United States Court for the District of Delaware, that the proposition assumed any real definiteness. The Hercules company was originally created by a decree of a federal court in an action brought by the United States against the du Pont company under the Sherman act. Although not a party to this action, the Hercules company is bound by certain injunctions in the final decree, and for this reason it was deemed necessary to petition the court for permission to effect the present transaction. On May 4, a decision was rendered on the Hercules company's petition, sanctioning the purchase of the Aetna company, in which the court expressed itself as convinced that in permitting the Hercules Powder Co. to buy the Aetna company actual competition would be undiminished and even probably increased, especially as regards the Hercules company's strongest rival, the du Pont company.

By this purchase the Hercules company will acquire high explosives, or dynamite, plants near Birmingham, Ala.; Emporium, Pa.; Sinnamahoning, Pa.; Ishpeming, Mich.; and Fayville, Ill.; two black blasting powder plants, one at Goes Station, Ohio, and the other near Birmingham, Ala.; a plant for the manufacture of blasting caps and electric blasting caps at Port Ewen, N. Y., and a plant for the manufacture of fulminate of mercury, for use in blasting caps, at Prescott, Ont., Canada.

The company states that reorganization and new alignments of branch office territories will take place gradually

Water Purification

The last meeting on the 1920-21 program of the Connecticut Valley Section of the A.C.S. was held in Westfield, Mass., on May 22. The members were entertained for dinner at the Mt. Tekoa Country Club. The afternoon was given up to a trip to the Borden Brook reservoir and filter plant, which forms a part of the water supply of Springfield, Mass. About thirty members made up the party for the trip and thanks to the courtesy of the members of the staff at the filter plant enjoyed a most instructive excursion.

Prof. Whipple, of the Harvard Engineering School, was the speaker at the evening meeting. His subject was "Water Purification."

Dr. Whipple showed a series of charts illustrating the various qualities of the waters of Massachusetts used for town and city water supplies. These charts showed color, sediment—the sediment in these waters is so slight that it cannot be expressed in terms of the silica standard—iron, hardness, chlorine and other factors. For the most part the waters of Massachusetts are low in color and in carbon dioxide and are in general very soft waters. Some, however, are quite corrosive.

Some recent European work, he said, has shown a balance between carbon dioxide, carbonate and bicarbonate. If there is more carbon dioxide in the water than this relation calls for, the waters are corrosive. For this reason apparently the most corrosive waters of the state are soft waters.

Filtration of waters to be successful must do much besides cleaning up water from a sanitary standpoint. Some methods now used increase corrosion by increasing the carbon dioxide and reducing the bicarbonates in water. For this reason alum is not entirely satisfactory as a coagulant. He said that we formerly considered that the action of alum in water was simple. It is now known to be very complex. Conductivity methods have shown this especially well. He referred to the article by Abel Wolman and Frank Hannan, published in CHEMICAL & METALLURGICAL ENGINEERING, vol. 24, pp. 728-34, as illustrating this point and invited contributions along such lines as this from all chemists who might find opportunity to do work in this field.

Study of the reactions involved in various methods for water-treating which would show the time necessary for the reaction to be completed is very necessary, he said, for if the time between treatment and filtering is too short the reaction will go to completion afterwards and will probably cause trouble. He read a letter from Allan Hazen bearing on this point specifically. Mr. Hazen believes that the time factor in settling of waters has been underestimated and that more attention must be paid to it. Some waters contain compounds which retard the formation of the alumina flock.

With regard to industrial water purification Dr. Whipple said that he believed that there was a relation between color and dissolved alumina. Sometimes waters are found that will not respond to a softening treatment until they are heated. Soft waters are the most troublesome in this respect. He thought that new methods might be worked out to largely replace those now in use.

The corrosive problem has not yet been properly handled. He quoted Prof. Phillips of Harvard, who believes that the presence of electric currents generated by couples formed at the junction of dissimilar elements may be a source of some of the trouble. Another factor of importance in water-treatment, especially where mechanical filters are used, is the handling of the alumina flock and its removal by the filter bed. Pipes of the largest diameter possible should be used to pass the water to the filters so as to have the stream flow as slowly as possible in order that the alumina flock may not be broken up.

To Extend Aid to Export Industries

Details of the plan of the Secretary of Commerce to aid the export industries now are being worked out. Each of the industries is to be separated into subdivisions. Three of the chemical subdivisions have been agreed upon and others are to be chosen later. The three subdivisions which have been decided upon at the time of this writing are dyes, drugs and phosphates.

Personal

E. D. FROHMAN, of the S. Obermayer Co., Pittsburgh, Pa., has gone to Europe, where he will make a special study of the application of high-temperature cements for boiler and metallurgical furnace linings.

ELLWOOD HENDRICK, consulting editor of CHEMICAL & METALLURGICAL ENGINEERING, received the honorary degree of Doctor of Science from Franklin and Marshall College of Lancaster, Pa., on Commencement Day, June 8.

SIDNEY D. KIRKPATRICK has joined the editorial staff of CHEMICAL & METALLURGICAL ENGINEERING, with headquarters in New York. He was until recently a chemical expert for the U. S. Tariff Commission, Washington, D. C.

HARAI R. LAYNG, of the Eureka Holly Mining Co., has resigned and is now practicing as a metallurgical engineer in San Francisco. He was superintendent of both the Holly and Bullwhacker mines, and later designed and constructed a 15-ton experimental chloridizing volatilization plant, completed last March.

C. E. MCQUIGG is continuing research work for the Union Carbide & Carbon Corporation at the new Long Island City laboratory, instead of at Niagara Falls, N. Y.

Dr. ERNEST FOX NICHOLS was inaugurated as president of the Massachusetts Institute of Technology, Cambridge, Mass., on June 8.

F. H. PENDLETON, formerly chemist with the New England Bureau of Tests of Boston and more recently research chemist with the Gorton-Pew Fisheries Co., Gloucester, Mass., has joined the staff of Skinner, Sherman & Esselen, Inc., Boston, Mass.

WALLACE SAVAGE has resigned as assistant editor of CHEMICAL & METALLURGICAL ENGINEERING to take effect June 30. He will devote his attention to the commercial development of an asphalt expansion joint designed by him for use in concrete construction.

WILFRED W. SCOTT has resigned as research chemist of the General Chemical Co. and has accepted the position of associate professor of chemistry in the Colorado School of Mines, Golden, Col.

T. F. SULLIVAN, who has been in charge of construction for the new paper mill of the Riordon Co., Ltd., at Temiskaming, Que., has accepted a position as sales engineer with the Springfield Boiler Co., Springfield, Ill.

Obituary

W. B. COGSWELL, founder of the Solvay Process Co., died recently at his home in New York of blood poisoning resulting from an infected middle ear.

JOHN W. LEITCH died at Minesbridge, England, on May 20. Mr. Leitch was the pioneer British manufacturer of TNT and during the early days of the war was called upon to supply this explosive, which was so badly needed that it was used at the front within forty-eight hours after being manufactured. His plant and services were put at the disposal of the War Office and formed the nucleus of the great government TNT works. The heavy work of the early years of the war so told upon his health that toward the end of 1916 he had a breakdown following an attack of influenza which left his heart seriously affected. He recovered sufficiently, however, to resume his activities and in 1919 was appointed chairman of the mission sent to study some of the dye works in the occupied area of the Rhine. The two-volume report of this investigation is an eloquent testimony of the work done by this mission.

Current Market Reports

The Chemical and Allied Industrial Markets

NEW YORK, June 13, 1921.

The heavy chemical market continues to show improvement, and activity is emphasized in several important items. It is sufficiently apparent that liquidation has brought about an actual shortage of goods in some instances and buyers have forced prices upward in their efforts to cover requirements. While this condition does not hold true throughout the entire list and while it is evident that manufacturers will readjust prices in some commodities, the fact that caustic soda, soda ash, oxalic acid, nitrite of soda and other important items have resisted any selling influence is quite significant that the bottom has practically been reached. If the strength shown in these commodities during the past week is to be permanent, then a decided improvement can be expected throughout the general list.

One of the most encouraging features was the intermingling of foreign inquiries with those for domestic requirements. It is reported that several inquiries were received from Italy, Mexico and the Far East. Europe is reported to have been in the market for numerous large quantities of caustic soda and in some instances these inquiries have turned into actual orders.

Importations have already been decreased since the new tariff legislation, which dampened the buying of foreign goods and shifted the inquiry to domestic materials. This has been particularly true in the case of oxalic acid. The heavy imports of oxalic, which have been flooding the country during the past six months, have been summarily stopped by a ruling from the Treasury Department classifying this article as a "synthetic organic chemical" and subject to the same license rulings as dyestuffs and intermediates under the emergency tariff measure. Quite a few importers, unaware that there would be any such decision, have been caught with goods afloat or ready to be shipped. The situation has thrown the market into confusion and holders of stocks in this country have forced their prices up as far as possible. Soda ash was among the commodities to report a net advance in the spot market at the close. Rumors were current throughout the week that buyers are greatly concerned over shipments of ash from England and many interests expected delays in view of the coal strike. The result was that domestic ash was taken and the buying movement was sufficiently heavy to reduce resale stocks and register a high market.

There was a noted improvement in the inquiry for caustic soda. It is stated that English caustic soda cannot be imported into this country below 5c. per lb. Small lots of bichromate of soda have attracted a great deal of attention from the consuming trade and the market recorded an advance for the week.

CHEMICALS

Small lot buying orders of *bichromate of soda* reached the open market in good volume during the past week and dealers have been able to advance quotations without much difficulty. It is the general opinion that the quantity of supplies in resale hands is comparatively small and there was a noticeable tightening up of offerings on various occasions. At the close the best price heard was 8¼c. per lb. with most sellers asking 8½c. for standard brand material. A noticeable improvement in the general inquiry for *caustic soda* has taken place during the period under review. Demand has emanated from both foreign and domestic sources and enough buying orders have been shot into the market to keep prices as high as $4.10 per 100 lb. Standard brands were offered sparingly in the late trading and the general outlook appeared quite favorable for maintenence of values. Outside makes were obtainable at a fraction below those named for standards. English caustic soda for shipment was offered at $5 per 100 lb. N. Y. Producers quote contracts for solid caustic at 3¼c. per lb., basis 60 per cent f.o.b. works, and 5c. per 100 lb. higher for single cars. Most dealers quoted *nitrite of soda* on spot at 7½@7¾c. per lb., and it is understood that small lot trading took place at 7¼c. per lb. and upward depending on seller. The feeling continues bullish in this material, although some factors are of the belief that the advancing tendency will likely be irregular on account of supplies being scattered. Spot *prussiate of soda* is quoted firm at 12¼@12½c. per lb., with sales noted at these figures. A fair inquiry is reaching the market for small lots and several interests are inclined to look for an advance in prices. There were rumors that eventually this chemical is likely to come under the same classification as oxalic acid and nitrite of soda, thereby requiring a license to import. Offerings of resale light *soda ash* continue quite small and dealers stated that it was doubtful if better than $2.20 per 100 lb. could be done on any sizable quantity in single bags. Small lots were quoted at $2.25@$2.35 per 100 lb. Barrels were quoted at $2.50@$2.60 ex-store N. Y. The call for less than carlots was reported active.

Imported *barium chloride* was offered on spot at $60 per ton and it is understood that some domestic goods can be purchased at the same price. Some business is reported in small quantities, but consumers show little interest in round lots at present. There was a noticeable scarcity of offerings in *oxalic acid* and prices were decidedly higher on a basis of 19½@20c. per lb. There was no lack of confidence on the part of dealers regarding the immediate trend of values. The ruling by the Government requiring a license to import this chemical is viewed by many to be a very strengthening factor. Leading producers of *zinc sulphate* have lowered their carlot price to $2.90 per 100 lb. Small lots are moving at various figures up to 3¾c. per lb. The demand has not shown very much activity of late and prices have been established on a basis more attractive to the consumer. Prices on *white arsenic* are quoted lower at 6½@7¼c. per lb. The demand has been extremely dull and stocks are heavy in many quarters. *Red arsenic* was also quoted slightly lower with the demand very slow. Quotations are now around 11@12c. per lb. Imported *ammonium nitrate* is offered around 7¾@8c. per lb., according to seller and quantity. A fair demand has been noted. *Red phosphorus* in makers' hands is held at 50c. per lb., but the French imported material is offered at 40c. *Yellow phosphorus* from producers is quoted at 35c. per lb., as against 30c. per lb. named by importers. Carlots of *carbon tetrachloride* are offered by manufacturers at 10½c. per lb. f.o.b. N. Y. Small lots of five drums are held all the way up to 12c. per lb. Resale material is occasionally offered below these figures, but attracts little attention.

COAL-TAR PRODUCTS

Producers of coal-tar products are firmer in their views in most quarters and if any shading is possible it is only among second hands. There is a difference of opinion as to supplies among second hands, and while some say the surplus has been very much reduced, there are some who feel that stocks are still plentiful and in consequence inquiries are more to test prices and are not frequently followed by orders. There was a considerable improvement noted in the general condition of the textile industry, which is already reflected in the dyestuff market by an increase in the demand for colors.

Among intermediates *beta naphthol* is in steady demand and prices are firmer in most directions, ranging from 38@40c. per lb. Makers of *para nitraniline* are quoting prices around 85@95c. per lb., with many resellers quoting the same figures. No definite lots could be located below this level, although the majority of resellers in the market seem to be of the opinion that business on a firm basis could easily be done at 82c. per lb. The determined effort on the part of some factors to keep prices up to 85c. per lb. rather lead to the belief that the market is not very firm. Prices on *para-nitrotoluene* are lower at 85@95c. per lb., according to quantity and seller. The market on *dimethylaniline* continues quiet with prices on the spot around 41@45c. per lb. There is a probability that this figure can be shaded on firm business, but stocks in most quarters are reported quite light.

Makers are holding their prices around 60@65c. per lb., according to quantity. The market on *aniline oil* seems somewhat steadier on an increasing inquiry. Spot resale stocks are being greatly depleted and inquiries are being turned over to producers. The general market price at present is around 20c. per lb. and business can be done freely at this level in spite of the high figures named by makers, up to 27c. per lb. *Naphthalene* continues dull with the inquiry very small and resale holders willing to make concessions to move stocks. Prices as low as 7½c. per lb. are named in some directions and it is understood that even these figures can be shaded on firm business. Holders of stocks seem to be getting very tired. Refiners are still holding their quotations at 8½@9½c. for the flake and 9½@10½c. per lb. for the balls, with very little business passing.

Waxes

Traders reported a quiet market for *beeswax*, but prices held on a steady basis in nearly all instances. Primary markets are well maintained. Crude African beeswax closed unchanged at 16½@17c. per lb. Brazilian crude held at 24½@26c. With little change at primary centers the market for *carnauba wax* showed no important price revisions locally. The volume of trading was quite easy, but no selling pressure was in evidence. No. 2 North Country held at 25@26c. per lb. spot delivery. No. 3 chalky closed at 17@18c. per lb., with the No. 3 North Country at 16@17c. per lb. No. 3 North Country for forward shipment held around 15c. per lb. Arrivals of *Japan wax* were larger, but this apparently was not reflected in any weakness in prices. Importers continue to quote the market at 18@18½c. per lb. for spot goods, while for near by slightly lower figures prevailed. Mail advices from Tokio reported a quiet but steady market despite the fairly liberal holdings. The market for *paraffine wax* again seemed to favor buyers and quotations were barely steady throughout the trade, with some prominent factors credited with shading in order to attract business. The export inquiry was dull. Stocks of paraffine are said to be large considering the amount of trading. Scale wax, 118-120 deg. melting point, was offered at 2½c. per lb. in carlots.

Vegetable Oils

Irregularity was noted in the prices named on *chinawood oil* for forward delivery and operators said that the situation was slightly easier. Offerings were noted at 10¾@11c. per lb. in barrels, June-July shipment from the Orient, New York basis. Spot oil was nominally unchanged around the 15c. level, although scattered lots sold at points outside at some concessions. Buying interest in *coconut oil* was confined chiefly to spot and near by, in barrels, for which prices held steady in all quarters. Refined edible oil was held at 12½@12¾c. per lb., cooperage basis. Ceylon style oil in barrels closed at 10½c. asked, but this figure was not firm. Loose oil for shipment from Manila was offered at 7⅜c., Coast basis, with buyers' ideas holding at 7½c. per lb. Copra was unchanged at 5c. asked, N. Y., and 4½c., nominal, Pacific Coast points. There were no sales reported. Crude domestic *peanut oil* held at 5¾@6c. per lb., buyers' tanks, f.o.b. mills. The demand was quiet and prices were barely steady. Oriental oil was in limited supply on the Coast and the prices were purely nominal around 6@6¼c. per lb., sellers' tanks. Deodorized oil in barrels held at 10½c. per lb., N. Y. Crude *soya bean oil* for prompt shipment held at 5⅝c. per lb., sellers' tanks, Coast, with offerings reported light. Soya bean oil in barrels was unchanged here at 7¾@8c. per lb.

The St. Louis Market

St. Louis, Mo., June 10, 1921.

A careful survey of the drug market disclosed that the second-hand lots in hands of weak holders are practically absorbed, which tended to give the market a better and firmer tone. The fine chemical business has been fairly good, while a more quiet condition prevails in the heavy and industrial chemical lines. Consumers are still indisposed to place large orders and anticipate their requirements. The commercial acids have improved considerably and orders of larger volume are being received.

The *caustic soda* demand continues very weak, with the big buyers adhering to the hand-to-mouth policy. Prices range from $3.85@$4.50 per 100 lb., basis 76 per cent, according to quantity purchased. The *soda ash* market is extremely dull with the prices still ranging at $2.90 per 100 lb. and upward. *Bicarbonate of soda* is being offered in less than carlot quantities at $2.50 per 100 lb., which figures less than the manufacturers' cost f.o.b. works, plus freight.

Industrial Chemicals

Sulphur continues to enjoy a fair demand with prices holding firm at $2 per 100 lb. for the commercial in bags. *Ammonia water* continued along the lines previously reported and some fair-sized orders are being placed. The *carbon bisulphide technical* market is not very active. The limited uses to which this material is put mitigate against an active market at this moment. *Copperas* has been slow and ruling at $19.50@$21 per ton. The *zinc* market has been very quiet the past week, with *sulphate* ruling at 3¼c. The *oxide leaded* 5 per cent is holding at 8c., while the *lead free* is ruling at 8¾c. *Soda hyposulphite* is enjoying a fair business in a routine way.

Drugs and Pharmaceuticals

Acetanilid has shown a stronger position lately. There is a limited demand for *acetphenetidin*. The *chloral hydrate* business is normal with a regular demand. *Bismuth* preparations are fairly active, but should show a greater demand, as this is the season for *bismuth salts*. The *bromides* continue to move in a very small way due to the large lots being sent into this market by the foreign manufacturers. There is a limited business transacted on *caffeine*. There has been a material increase in business for *scale salts*, particularly the iron and ammonium citrate brown scales, which has been moving very briskly in the last week or two. *Cream of tartar* is enjoying a very good demand and orders of large volume are being filled. *Ether* is holding its own. *Glycerophosphates* are moving very well at factor's schedule. The second-hand lots of *iodides* that are still disturbing this market tend to keep down an increase in business and manufacturers are getting only their routine business. Manufacturers have reduced their prices on *hard mercurials* with a fair demand. A fair-sized business on *saccharine* is reported and factors are in position to fill orders promptly. The demand for *sodium benzoate* is keeping pace with the season, and manufacturers report a brisk movement. Now that prices on *salicylates* seem to be more firmly established, there has been a noticeable increase in the demand. *Glycerine* is being freely contracted for at 16½c. for six months with protection, and buyers are urged to take advantage of what is generally considered too low a price for this item.

Acids

Manufacturers report an improvement in the demand for *hydrochloric*, *nitric* and *sulphuric*, commercial grades, which they attribute to the fact that many industrial plants are again in operation. *Carbolic acid crystals* has enjoyed a better demand recently. The demand for *citric acid* at this moment is practically nil, due to the unseasonable weather for soft drinks, but stocks should not be allowed to decrease as the summer season is just beginning. Due to the resumption of aniline dye manufacture, there has been a noticeable increase in the demand for *gallic acid*. The status of *phosphoric acid sirupy* is the same as *citric*, as the two commodities are allied in the manufacture of soft drinks. *Salicylic acid* is moving briskly and being a seasonable product a larger volume of business is to be expected. The market on *tartaric acid* has been firm and commanding a good demand. The *tannic acid* market is firm with a fair business.

Vegetable Oils

Linseed reached a maximum of 80c. and today holds at 78c. in cooperage from warehouse. The general impression of the trade is that even higher prices may prevail. *Turpentine* demand is routine with price at 61c. unfirm. The price of 10½c. for *castor oil* in drums continues very firm in spite of only a fair demand.

The Iron and Steel Market

PITTSBURGH, June 10, 1921.

The steel market in the past week has given a fresh exhibition of the depth of dullness to which it can sink. Literally an order for 100 tons is now a large one for a steel mill, and even carload orders are scarce.

STEEL PRODUCTION

The monthly report of the American Iron and Steel Institute, showing steel ingot production in May, indicates that the month's production was larger than had been estimated, even at the close of the month, for the rate of output was substantially the same as the rate in April, and indeed a shade heavier. The May average was, however, made up by a considerably higher rate than the average at the beginning of the month and a considerably lower rate at the close. An item in the same connection is that while the total output was about the same for the two months, the independents produced more in May than in April, while the Steel Corporation produced less.

Production of steel ingots, which was at a shade above 30 per cent of capacity in both April and May, is now at a rate of about 25 per cent, possibly somewhat less, and the present outlook, based on the extremely light buying and specifying of the past few days, is that a rate of 20 per cent or less will be reached before the end of June, making production at about 10,000,000 tons per annum, equal to the output in 1900, the year before the Steel Corporation was formed.

In recent weeks the steel trade has endeavored to form a conception of what is "the minimum rate of consumption" of steel, assuming simply the condition of there being "hard times" or "a severe industrial depression." Experience before the war showed that production never dropped below about 50 per cent of capacity, and it looked as if there might be a rule. The recent effort has been abandoned, it being made quite clear that the flow of steel from mills is not in relation to the severity of a business depression. The flow of steel could stop entirely and yet for a time the major part of the business of the country could be conducted, for the various users of steel could get along, to an extent, with what they had.

It is seen now that there must be a liquidation of stocks all along the line, not simply of stocks of steel in the hands of manufacturing consumers, but of stocks of their finished wares, whether in the hands of the manufacturers or the distributors, and the general public, the ultimate buyer, must develop a desire to buy and accumulate an ability. The process is expected to be slow, but the low point for many years in the flow of steel from mill is likely to be reached within a very few weeks. The probability is very strong that there will be an upturn in August, but it will be an upturn from such a low point that it will be gratifying chiefly as showing a trend in the right direction.

STEEL PRICES

It is said that there is "an open market" in steel products, though the term is not precisely defined. The attitude of the majority of sellers is that they have no particular incentive to maintain the prices lately in force and will make concessions in price if thereby they can get orders that are worth while. The difficulty is that practically no business is offered. There is reason to believe that the Steel Corporation will not do as it did last February and March, when it adhered to its regular prices despite cutting by practically all the independents. This time it is likely the corporation will meet any widespread cutting by independents. In wire products the corporation has already done this, and nails, plain wire and galvanized barb wire are quotable respectively at $3, 2.75c. and 3.85c., or $5 a ton below what are known as April prices. Plates, formerly at 2.20c., have sold at 2c. even in small lots, though it is not known at this writing that the Steel Corporation has met the figure. Shading in sheets is growing.

PIG IRON

Foundry pig iron at valley furnaces is off 5c. to $22.50. Basic, which was uncertain at $21.75, is now plainly quotable to $21.50, bessemer remaining at $23.

General Chemicals

CURRENT WHOLESALE PRICES IN NEW YORK MARKET

		Carlots	Less Carlots
Acetic anhydride	lb.	..... –	$0.40 – $0.45
Acetone	lb.	$0.12½ – $0.12¾	.13 – .13½
Acid, acetic, 28 per cent	100 lbs.	2.50 – 2.75	3.00 – 3.25
Acetic, 56 per cent	100 lbs.	4.00 – 4.25	4.50 – 5.50
Acetic, glacial, 99½ per cent, carboys,	100 lbs.	9.75 – 10.00	10.25 – 10.50
Boric, crystals	lb.	.13½ – .14	.14½ – .15
Boric, powder	lb.	.15 – .15½	.16 – .16½
Citric	lb.	..... –	.45 – .46
Hydrochloric	100 lb.	1.50 – 1.65	1.75 – 2.00
Hydrofluoric, 52 per cent	lb.	.12½ – .12½	.12½ – .13
Lactic, 44 per cent tech	lb.	.10 – .11	.11½ – .12
Lactic, 22 per cent tech	lb.	.04½ – .05½	.06 – .07
Molybdic, C. P.	lb.	4.00 – 4.50	4.50 – 5.00
Muriatic, 20 deg. (see hydrochloric)	....	..... –	..... – .....
Nitric, 40 deg	lb.	.06½ – .06¾	.07 – .07½
Nitric, 42 deg	lb.	.07¼ – .07½	.07¼ – .08¼
Oxalic, crystals	lb.	.19½ – .20	.21 – .22
Phosphoric, Ortho, 50 per cent solution	lb.	.17 – .17½	.18 – .19
Picric	lb.	.20 – .25	.27 – .35
Pyrogallic, resublimed	lb.	..... –	1.90 – 2.15
Sulphuric, 60 deg., tank cars	ton	..... –	11.50 – 13.00
Sulphuric, 60 deg., drums	ton	..... –	13.00 – 15.00
Sulphuric, 66 deg., tank cars	ton	18.00 – 20.00	..... – .....
Sulphuric, 66 deg., drums	ton	22.00 – 22.50	23.00 – 23.50
Sulphuric, 66 deg., carboys	ton	..... –	..... – .....
Sulphuric, fuming, 20 per cent (oleum) tank cars	ton	23.00 – 24.00	..... – .....
Sulphuric, fuming, 20 per cent (oleum) drums	ton	25.00 – 26.00	26.50 – 27.00
Sulphuric, fuming, 20 per cent (oleum) carboys	ton	31.00 – 32.00	33.00 – 34.00
Tannic, U. S. P.	lb.	..... –	.90 – 1.00
Tannic (tech.)	lb.	.50 – .52	.54 – .57
Tartaric, crystals	lb.	..... –	.30 – .32
Tungstic, per lb. of WO	lb.	..... –	1.30 – 1.40
Alcohol, Ethyl	gal.	..... –	4.75 – 4.95
Alcohol, Methyl (see methanol)	....	..... –	..... – .....
Alcohol, denatured, 188 proof	gal.	..... –	.31 – .36
Alcohol, denatured, 190 proof	gal.	..... –	.38 – .42
Alum, ammonia lump	lb.	.03½ – .03¾	.04 – .04½
Alum, potash lump	lb.	.03¾ – .04	.04¼ – .04½
Alum, chrome lump	lb.	.13 – .13½	.14 – .14½
Aluminum sulphate, commercial	lb.	.01½ – .02	.02½ – .02½
Aluminum sulphate, iron free	lb.	.03 – .03½	.03½ – .04
Aqua ammonia, 26 deg., drums (750 lb.)	lb.	.07½ – .07¾	.08 – .08¼
Ammonia, anhydrous, cyl. (100-150 lb.)	lb.	.30 – .32	.33 – .35
Ammonium carbonate, powder	lb.	.08 – .08½	.09 – .10
Ammonium chloride, granular (white salammoniac)	lb.	.06½ – .06¾	.07 – .07½
Ammonium chloride, granular (gray salammoniac)	lb.	.07½ – .08	.08¼ – .08½
Ammonium nitrate	lb.	.07½ – .07¾	.08 – .08½
Ammonium sulphate	100 lb.	2.50 – 2.75	2.80 – 2.90
Amylacetate	gal.	..... –	4.00 – 4.25
Amylacetate tech	gal.	..... –	2.50 – 3.00
Arsenic oxide, (white arsenic) powdered	lb.	.06½ – .07	.07½ – .08
Arsenic, sulphide, powdered (red arsenic)	lb.	.11 – .11½	.12 – .13
Barium chloride	ton	60.00 – 62.00	63.00 – 65.00
Barium dioxide (peroxide)	lb.	.19 – .20	.21 – .22
Barium nitrate	lb.	.08½ – .09	.09½ – .10
Barium sulphate (precip.) (blanc fixe)	lb.	.04½ – .05	.05½ – .06
Bleaching powder (see calc. hypochlorite)	....	..... –	..... – .....
Blue vitriol (see copper sulphate)	....	..... –	..... – .....
Borax (see sodium borate)	....	..... –	..... – .....
Brimstone (see sulphur, roll)	....	..... –	..... – .....
Bromine	lb.	.41 – .42	.43 – .45
Calcium acetate	100 lbs.	2.00 – 2.05	..... – .....
Calcium carbide	lb.	.05½ – .05¾	.06 – .06½
Calcium chloride, fused, lump	ton	24.00 – 25.00	26.00 – 27.00
Calcium chloride, granulated	lb.	.01½ – .02	.02¼ – .02½
Calcium hypochlorite (bleach powder)	100 lb.	2.15 – 2.25	2.35 – 2.50
Calcium peroxide	lb.	..... –	1.40 – 1.50
Calcium phosphate, tribasic	lb.	..... –	.15 – .16
Camphor	lb.	..... –	.70 – .72
Carbon bisulphide	lb.	.06½ – .07	.07½ – .08
Carbon tetrachloride, drums	lb.	.10½ – .10½	.11 – .12
Carbonyl chloride (phosgene)	lb.	..... –	.75 – 1.00
Caustic potash (see potassium hydroxide)	....	..... –	..... – .....
Caustic soda (see sodium hydroxide)	....	..... –	..... – .....
Chlorine, gas, liquid-cylinders (100 lb.)	lb.	.08 – .09	.09½ – .10
Chloroform	lb.	..... –	.42 – .44
Cobalt oxide	lb.	..... –	3.00 – 3.10
Copperas (see iron sulphate)	....	..... –	..... – .....
Copper carbonate, green precipitate	lb.	.20 – .21	.22 – .23
Copper cyanide	lb.	..... –	.50 – .62
Copper sulphate, crystals	lb.	.05½ – .05¾	.06 – .06½
Cream of tartar (see potassium bitartrate)	....	..... –	..... – .....
Epsom salt (see magnesium sulphate)	....	..... –	..... – .....
Ethyl Acetate Com. 85%	gal.	..... –	1.00 – 1.05
Ethyl Acetate pure (acetic ether 98% to 100%)	lb.	..... –	.50 – .52
Formaldehyde, 40 per cent	lb.	.14 – .14½	.14¾ – .15
Fusel oil, ref.	gal.	..... –	3.00 – 3.25
Fusel oil, crude	gal.	..... –	1.75 – 2.00
Glauber's salt (see sodium sulphate)	....	..... –	..... – .....
Glycerine, C. P. drums extra	lb.	..... –	.16 – .16½
Iodine, resublimed	lb.	..... –	3.65 – 3.75
Iron oxide, red	lb.	..... –	.10 – .20
Iron sulphate (copperas)	100 lb.	1.00 – 1.25	1.50 – 1.75
Lead acetate	lb.	..... –	.11½ – .13½
Lead arsenate, paste	lb.	.09 – .09½	.10 – .11
Lead nitrate	lb.	..... –	.15 – .20
Litharge	lb.	.08¼ – .08½	.08¾ – .09
Lithium carbonate	lb.	..... –	1.30 – 1.40
Magnesium carbonate, technical	lb.	.09 – .09½	.10 – .11
Magnesium sulphate, U. S. P.	100 lb.	2.75 – 3.00	..... – .....
Magnesium sulphate, technical	100 lb.	..... –	1.10 – 2.25
Methanol, 95%	gal.	..... –	.75 – .77
Methanol, 97%	gal.	..... –	.78 – .82
Nickel salt, double	lb.	..... –	.14 – .14½
Nickel salt, single	lb.	..... –	.15 – .15½
Phosgene (see carbonyl chloride)	....	..... –	..... – .....
Phosphorus, red	lb.	.45 – .46	.47 – .50
Phosphorus, yellow	lb.	..... –	.35 – .37
Potassium bichromate	lb.	.11¾ – .12	.12¼ – .12½

		Carlots	Less Carlots
Potassium bitartrate (cream of tartar)	lb.	$ – $	$0.31 – $0.32
Potassium bromide, granular	lb.	–	.16 – .25
Potassium carbonate, U. S. P.	lb.	.35 – .40	.45 – .50
Potassium carbonate, 80–85%	lb.	.06 – .06½	.06½ – .07½
Potassium chlorate, crystals	lb.	.08½ – .10	.10½ – .14
Porassium cyanide	lb.	–	.26 – .28
Potassium hydroxide (caustic p tash)	lb.	.05½ – .05¾	.05¾ – .08
Potassium muriate, 80% K.C.	ton	50.00 – 53.00	
Potassium iodide	lb.	–	2.75 – 3.00
Potassium nitrate	lb.	.09¼ – .09½	.10 – .12¼
Potassium permanganate	lb.	.31 – .32	.33 – .34
Potassium prussiate, red	lb.	.35 – .37	.38 – .40
Potassium prussiate, yellow	lb.	.24 – .24½	.25 – .26
Potassium sulphate (powdered)	per unit	–	1.50 – 1.75
Rochelle salts (see sodium potas tartrate)		–	–
Salammoniac (see ammonium chloride)		–	–
Sal soda (see sodium carbonate)		–	–
Salt cake	ton	–	32.00 – 33.00
Silver cyanide	oz.	–	1.35 – 1.38
Silver nitrate	oz.	–	.40 – .41
Soda ash, light	100 lb.	2.25 – 2.30	2.40 – 2.75
Soda ash, dense	100 lb.	2.45 – 2.50	2.60 – 2.75
Sodium acetate	lb.	.04½ – .04¾	.05 – .05½
Sodium bicarbonate	100 lb.	2.25 – 2.40	2.50 – 2.75
Sodium bichromate	lb.	.08½ – .08	.09 – .10
Sodium bisulphate (nitre cake)	ton	5.00 – 5.25	5.50 – 6.50
Sodium bisulphite powdered, U.S.P.	lb.	.05½ – .05½	.05¾ – .06½
Sodium borate (borax)	lb.	.06½ – .06½	.07 – .07½
Sodium carbonate (sal soda)	100 lb.	1.90 – 2.00	2.10 – 2.40
Sodium chl rate	lb.	.07½ – .07½	.08 – .08½
Sodium cyanide	lb.	.22 – .24	.25 – .30
Sodium fluoride	lb.	.12 – .12½	.13 – .14
Sodium hydroxide (caustic soda)	100 lb.	4.00 – 4.05	4.10 – 4.50
Sodium hyposulphite	l.	–	.03½ – .03¾
Sodium nitrate	100 lb.	2.90 –	3.00 –
Sodium nitrite	lb.	.07¾ – .08	.08½ – .10
Sodium peroxide, powdered	lb.	.25 – .26	.27 – .30
Sodium phosphate, dibasic	lb.	.04½ – .04¾	.05 – .05½
Sodium potassium tartrate (Rochelle salts)	lb.	–	.26 – .27
Sodium prussiate, yellow	lb.	.12¼ – .12½	.12½ – .13
Sodium silicate, solution (40 deg.)	lb.	1.25 – 1.35	1.40 – 1.50
Sodium silicate, solution (60 deg.)	lb.	.02¾ – .03	.03¼ – .03¾
Sodium sulphate, crystals (Glauber's salt)	100 lbs.	1.50 – 1.75	2.00 – 2.25
Sodium sulphide, fused, 60-62 per cent (conc.)	lb.	.05½ – .05¾	.06 – .06½
Sodium sulphite, crystals	lb.	.03½ – .04	.04¼ – .04½
Strontium nitrate, powdered	lb.	.15 – .15½	.16 – .17
Sulphur chl ride, red	lb.	.07 – .07½	.07½ – .08
Sulphur, crude	ton	20.00 – 22.00	–
Sulphur dioxide, liquid, cylinders extra	lb.	.08 – .08½	.09 – .10
Sulphur (sublimed), flour	100 lb.	–	2.25 – 3.10
Sulphur, roll (brimstone)	100 lb.	–	2.00 – 2.75
Tin bichloride, 50 per cent	lb.	.18 – .19	–
Tin oxide	lb.	–	.40 – .42
Zinc carbonate, precipitate	lb.	.16 – .18	.19 – .20
Zinc chloride, gran	lb.	.11 – .11¾	.11½ – .12
Zinc cyanide	lb.	.45 – .49	.50 – .60
Zinc dust	lb.	.12 – .13	.13½ – .14
Zinc oxide, XX	lb.	.09 – .09¼	.09½ – .10
Zinc sulphate	100 lb.	2.90 – 3.00	3.25 – 3.75

Coal-Tar Products

NOTE—The following prices are for original packages in large quantities:

Alpha-naphthol, crude	lb.	$1.10 — $1.15
Alpha-naphthol, refined	lb.	1.25 — 1.30
Alpha-naphthylamine	lb.	.35 — .40
Aniline oil, drums extra	lb.	.20 — .27
Aniline salts	lb.	.26 — .29
Anthracene, 80% in drums (100 lb.)	lb.	.75 — 1.00
Benzaldehyde U.S.P.	lb.	1.50 —
Benzidine, base	lb.	.85 — 1.00
Benzidine sulphate	lb	.75 — .85
Benzoic acid, U.S.P.	lb.	.60 — .65
Benzoate of soda, U.S.P.	lb.	.65 — .70
Benzene, pure, water-white, in drums (100 gal.)	gal.	.27 — .32
Benzene, 90%, in drums (100 gal.)	gal.	.25 — .28
Benzyl chloride, 95-97%, refined	lb.	.28 — .30
Benzyl chloride, tech	lb.	.20 — .25
Beta-naphthol benzoate	lb.	3.50 — 4.00
Beta-naphthol, sublimed	lb.	.70 — .75
Beta-naphthol, tech	lb.	.38 — .40
Beta-naphthyla mine, sublimed	lb.	2.00 — 2.25
Cresol, U. S. P., in drums (100 lb.)	lb.	.16 — .18
Ortho-cresol, in drums (100 lb.)	lb.	.25 — .27
Cresylic acid, 97–99%, straw color, in drums	gal.	.70 — .80
Cresylic acid, 95-97%, dark, in drums	gal.	.65 — .70
Cresylic acid, 50%, first quality, drums	gal.	.45 — .50
Dichlorbenzene	lb.	.06 — .09
Diethylaniline	lb.	1.20 — 1.25
Dimethylaniline	lb.	.41 — .50
Dinitrobenzene	lb.	.32 — .35
Dinitroclorbenzene	lb.	.20 — .30
Dinitronaphthalene	lb.	.30 — .40
Dinitrophenol	lb.	.35 — .40
Dinitrotoluene	lb.	.27 — .30
Dip oil, 25%, car lots, in drums	gal.	.40 — .45
Diphenylamine	lb.	.60 — .65
H-acid	lb.	1.25 — 1.35
Meta-phenylenediamine	lb.	1.15 — 1.20
Monochlorbenzene	lb.	.12 — .14
Monoethylaniline	lb.	1.75 — 1.85
Naphthalene crushed, in bbls.	lb.	.07½ — .08½
Naphthalene, flake	lb.	.07½ — .08½
Naphthalene, balls	lb.	.08¼ — .09½
Naphthionic acid, crude	lb.	.70 — .75
Nitrobenzene	lb.	.12 — .15
Nitro-naphthalene	lb.	.30 — .35
Nitro-toluene	lb.	.15 — .18
Ortho-amidophenol	lb.	3.10 — 3.20
Ortho-dichlor-benzene	lb.	.15 — .20
Ortho-nitro-phenol	lb.	.80 — .85
Ortho-nitro-toluene	lb.	.15 — .20
Ortho-toluidine	lb.	.20 — .25
Para-amidophenol, base	lb.	1.50 — 1.60
Para-amidophenol, HCl	lb.	1.75 — 1.80
Para-dichlorbenzene	lb.	.15 — .20
Paranitroaniline	lb.	.85 — 1.00
Para-nitrotoluene	lb.	.85 — .95
Para-phenylenediamine	lb.	1.80 — 2.00
Para-toluidine	lb.	1.25 — 1.40
Phthalic anhydride	lb.	.50 — .60
Phenol, U. S. P., drums	lb.	.11 — .13
Pyridine	gal.	2.00 — 3.50
Resorcinol, technical	lb.	1.75 — 1.85
Resorcinol, pure	lb.	2.25 — 2.30
Salicylic acid, tech., in bbls.	lb.	.21 — .22
Salicylic acid, U. S. P.	lb.	.24 — .25
Salol	lb.	.80 — .85
Solvent naphtha, water-white, in drums, 100 gal.	gal.	.25 — .28
Solvent naphtha, crude, heavy, in drums, 100 gal.	gal.	.14 — .16
Sulphanilic acid, crude	lb.	.30 — .35
Tolidine	lb.	1.25 — 1.35
Toluidine, mixed	lb.	.40 — .45
Toluene, in tank cars	gal.	.25 — .28
Toluene, in drums	gal.	.28 — .31
Xylidines, drums, 100 gal.	lb.	.40 — .45
Xylene, pure, in drums	gal.	.40 — .45
Xylene, pure, in tank cars	gal.	.45 —
Xylene, commercial, in drums, 100 gal.	gal.	.33 — .35
Xylene, commercial, in tank cars	gal.	.30 —

Waxes

Prices based on original packages in large quantities.

Beeswax, refined, dark	lb.	$0.23 — $0.25
Beeswax, refined, light	lb.	.25 — .27
Beeswax, white pure	lb.	.42 — .45
Carnauba, Flora	lb.	.62 — .63
Carnauba, No. 2, North Country	lb.	.27 — .28
Carnauba, No. 3, North Country	lb.	.16 — .17
Japan	lb.	.18 — .18½
Montan, crude	lb.	.07 — .07½
Paraffine waxes, crude match wax (white) 105-110 m.p.	lb.	.03½ — .03½
Paraffine waxes, crude, scale 124-126 m.p.	lb.	.02½ —
Paraffine waxes, refined, 118-120 m.p.	lb.	.03½ — .03½
Paraffine waxes, refined, 125 m.p.	lb.	.04½ — .04½
Paraffine waxes, refined, 128-130 m.p.	lb.	.04½ — .05
Paraffine waxes, refined, 133-135 m.p.	lb.	.05¼ — .05¼
Paraffine waxes, refined, 135-137 m.p.	lb.	.05½ — .06
Stearic acid, single pressed	lb.	.09½ —
Stearic acid, double pressed	lb.	.10 —
Stearic acid, triple pressed	lb.	.11 — .11¼

Naval Stores

All prices are f.o.b. New York unless otherwise tated, and are based on carload lots. The oils in 50-gal. bbls., gross weight, 500 lb.

Rosin B-D, bbl.	280 lb.	$5.10 —	
Rosin E-I	280 lb.	5.80 —	6.00
Rosin K-N	280 lb.	6.50 —	6.70
Rosin W. G.-W. W.	280 lb.	6.80 —	
Wood rosin, bbl.	280 lb.	6.25 —	
Spirits of turpentine	gal.	.62 —	
Wood turpentine, steam dist.	gal.	.60 —	
Wood turpentine, dest. dist.	gal.	.58 —	
Pine tar pitch, bbl	200 lb.	—	6.75
Tar, kiln burned, bbl. (500 lb.)	bbl.	—	11.50
Retort tar, bbl.	500 lb.	—	11.50
Rosin oil, first run	gal.	.36 —	
Rosin oil, second run	gal.	.38 —	
Rosin oil, third run	gal.	.43 —	
Pine oil, steam dist., sp.gr., 0.930-0.940	gal.		$1.80
Pine oil, pure, dest. dist.	gal.		1.50
Pine tar oil, ref., sp.gr. 1.025-1.035	gal.		.46
Pine tar oil, crude, sp.gr. 1.025-1.035 tank cars f.o.b. Jacksonville, Fla.	gal.		.35
Pine tar oil, double ref., sp.gr. 0.965-0.990	gal.		.75
Pine tar, ref., thin, sp.gr., 1.080-1.960	gal.		.35
Turpentine, crude, sp. gr., 0.900-0.970	gal.		1.20
Hardwood oil, f.o.b. Mich., sp.gr., 0.960-0.990	gal.		.35
Pinewood creosote, ref.	gal.		.52

Solvents

73-76 deg., steel bbls. (85 lb.)	gal.	$0.41
70-72 deg., steel bbls. (85 lb.)	gal.	.39
68-70 deg., steel bbls. (85 lb.)	gal.	.38
V. M. and P. naphtha, steel bbls. (85 lb.)	gal.	.30

Crude Rubber

Para—Upriver fine	lb.	$0.16 —	.17
Upriver coarse	lb.	.09 —	.09¼
Upriver caucho ball	lb.	.11½ —	.12
Plantation—First latex crepe	lb.	.15½ —	
Ribbed smoked sheets	lb.	.14 —	.14¼
Brown crepe, thin, clean	lb.	.15 —	
Amber crepe No. 1	lb.	.17 —	

Oils

VEGETABLE

The following prices are f.o.b. New York for carload lots.

Castor oil, No. 3, in bbls.	lb.	$0.08½ —	$0.09
Castor oil, AA, in bbls.	lb.	.10 —	.10¼
China wood oil, in bbls. (f.o.b. Pac. coast)	lb.	.11 —	.11½
Cocoanut oil, Ceylon grade, in bbls.	lb.	.10½ —	.10¾
Cocoanut oil, Cochin grade, in bbls.	lb.	.11½ —	.11¾
Corn oil, crude, in bbls.	lb.	.07¼ —	.08
Cottonseed oil, crude (f. o. b. mill)	lb.	.05½ —	.05½
Cottonseed oil, summer yellow	lb.	.07¼ —	.08
Cottonseed oil, winter yellow	lb.	.08 —	
Linseed oil, raw, car lots (domestic)	gal.	.76 —	
Linseed oil, raw, tank cars (domestic)	gal.	.70 —	
Linseed oil, in 5-bbl lots (domestic)	gal.	.79 —	

Olive oil, Denatured	gal.	$1.40 —	$1.60
Palm, Lagos	lb.	.06½ —	.07
Palm, Niger	lb.	.05½ —	.06
Peanut oil, crude, tank cars (f.o.b. mill)	lb.	.05½ —	.06
Peanut oil, refined, in bbls	lb.	.10½ —	.10¾
Rapeseed oil, refined in bbls	gal.	.86 —	.88
Rapeseed oil, blown, in bbls	gal.	.92 —	.94
Soya bean oil (Manchurian), in bbls. N. Y.	lb.	.07½ —	....
Soya bean oil, tank cars, f.o.b., Pacific coast	lb.	.04½ —	....
FISH			
Light pressed menhaden	gal.	$0.40 —	$0.41
Yellow bleached menhaden	gal.	.42 —	....
White bleached menhaden	gal.	.44 —	....
Blown menhaden	gal.	.80 —	....

Miscellaneous Materials

All f.o.b. New York Unless Otherwise Stated

Barytes, ground, white, f.o.b. Kings Creek, S. C.	net ton	$24.00 —	30.00
Barytes, ground, off color, f.o.b. Kings Creek	net ton	22.00 —	26.00
Barytes, crude, 88%@94% ba., Kings Creek	net ton	10.00 —	15.00
Barytes, floated, f.o.b. St. Louis	net ton	26.50 —	28.00
Barytes, crude, first grade, Missouri	net ton	7.00 —	....
Blanc fixe, dry	lb.	.05 —	.05½
Blanc fixe, pulp	net ton	50.00 —	60.00
Casein	lb.	.14 —	.16
Chalk, domestic, extra light	lb.	.05 —	.05½
Chalk, domestic, light	lb.	.04½ —	.05
Chalk, domestic, heavy	lb.	.04 —	.05
Chalk, English, extra light	lb.	.05 —	.07
Chalk, English, light	lb.	.05 —	.06
Chalk, English, dense	lb.	.04½ —	.05
China clay (kaolin) crude, f.o.b. mines, Georgia	net ton	8.00 —	10.00
China clay (kaolin) washed, f.o.b. Georgia	net ton	12.00 —	15.00
China clay (kaolin) powdered, f.o.b. Georgia	net ton	18.00 —	22.00
China clay (kaolin) crude f.o.b. Virginia points	net ton	8.00 —	12.00
China clay (kaolin) ground, f.o.b. Virginia points	net ton	15.00 —	40.00
China clay (kaolin), imported, lump	net ton	23.00 —	25.00
China clay (kaolin), imported, powdered	net ton	30.00 —	35.00
Feldspar, crude, f.o.b. Maryland and North Carolina points	gross ton	8.00 —	14.00
Feldspar, crude, f.o.b. Maine	net ton	7.50 —	10.00
Feldspar, ground, f.o.b. Maine	net ton	21.00 —	23.00
Feldspar, ground, f.o.b. North Carolina	net ton	17.00 —	21.00
Feldspar, ground, f.o.b. N. Y. State	net ton	17.00 —	21.00
Feldspar, ground, f.o.b. Baltimore	net ton	27.00 —	30.00
Fullers earth, f.o.b. Mines	net ton	16.00 —	17.00
Fullers earth, granular, f.o.b. Pa.	net ton	15.00 —	18.00
Fullers earth, powdered, f.o.b. Fla.	net ton	18.00 —	....
Fullers earth, imported, powdered	net ton	24.00 —	27.00
Graphite, Ceylon lump, first quality	lb.	.07½ —	.08
Graphite, Ceylon chip	lb.	.06 —	.06½
Graphite, high grade amorphous crude	lb.	.02½ —	.03
Pumice stone, imported, lump	lb.	.04 —	.50
Pumice stone, domestic lump	lb.	.05 —	.05½
Pumice stone, ground	lb.	.06 —	.07
Quartz (acid tower) first to head, f.o.b. Baltimore	net ton	.... —	10.00
Quartz (acid tower) 1¼@2 in., f.o.b. Baltimore	net ton	.... —	14.00
Quartz (acid tower) rice, f.o.b. Baltimore	net ton	.... —	17.00
Quartz, lump, f.o.b. North Carolina	net ton	5.00 —	7.50
Shellac, orange fine	lb.	.75 —	....
Shellac, orange superfine	lb.	.79 —	.82
Shellac, A. C. garnet	lb.	.55 —	.58
Shellac, T. N.	lb.	.70 —	.72
Soapstone	ton	12.00 —	15.00
Sodium chloride	long ton	12.50 —	13.00
Talc, paper-making grades, f.o.b. Vermont	ton	11.00 —	20.00
Talc, roofing grades, f.o.b. Vermont	ton	8.50 —	13.00
Talc, rubber grades, f.o.b. Vermont	ton	11.00 —	18.00
Talc, powdered, Southern, f.o.b. cars	ton	10.00 —	14.00
Talc, imported	ton	35.00 —	40.00
Talc, California talcum powder grade	ton	18.00 —	40.00

Refractories

Bauxite brick, 56% Al, f.o.b. Pittsburgh	per ton	$35.00–50.00	
Carborundum refractory brick, 9-in.	less than carlot	1.000	1250.00
	carload lots	1.000	1100.00
Chrome brick, f.o.b. Eastern shipping points	net ton	75– 90	
Chrome cement, 40–45% Cr_2O_3	net ton	45– 50	
Chrome cement, 40–45% Cr_2O_3, sacks, in car lots, f.o.b. Eastern shipping points	net ton	....	55
Fireclay brick, 1st quality, 9-in. shapes, f.o.b. Pennsylvania, Ohio and Kentucky works	1,000	40– 50	
Fireclay brick, 2nd quality, 9-in. shapes, f.o.b. Pennsylvania, Ohio and Kentucky works	1,000	40– 50	
Magnesite brick, 9-in. straight	net ton	90	
Magnesite brick, 9-in. arches, wedges and keys	net ton	100	
Magnesite brick, soaps and splits	net ton	110	
Silica brick, 9-in. sizes, f.o.b. Chicago district	1,000	45– 55	
Silica brick, 9-in. sizes, f.o.b. Birmingham district	1,000	45– 55	
Silica brick, 9-in. sizes, f.o.b. Mt. Union, Pa.	1,000	45– 55	

Ferro-Alloys

All f.o.b. Works

Ferro-titanium, 15-18%, f.o.b. Niagara Falls, N. Y.	net ton	$200.00 —	$225.00
Ferrochrome per lb. of Cr. contained, 6–8% carbon, carlots	lb.	.15 —	.16
Ferrochrome, per lb. of Cr. contained, 4-6% carbon, carlots	lb.	.16 —	.17
Ferromanganese, 76-80% Mn, domestic	gross ton	75.00 —	80.00
Ferromanganese, 76-80% Mn, English	gross ton	75.00 —	80.00
Spiegeleisen, 18-22% Mn	gross ton	30.00 —	32.00
Ferromolybdenum, 50-60% Mo, per lb. of Mo	lb.	2.50 —	....
Ferrosilicon, 10-15%	gross ton	45.00 —	50.00
Ferrosilicon, 50%	gross ton	75.00 —	80.00
Ferrosilicon, 75%	gross ton	140.00 —	145.00
Ferrotungsten, 70-80%, per lb. of contained W	lb.	.45 —	.50
Ferrouranium, 35-50% of U, per lb. of U content	lb.	6.00 —	....
Ferrovanadium, 30-40% per lb. of contained V	lb.	5.00 —	6.50

Ores and Semi-finished Products

All f.o.b. New York, Unless Otherwise Stated

Bauxite, 52% Al content	gross ton	$8.00 —	$10.00
Chrome ore, Calif. concentrates, 50% min. Cr_2O_3	unit	.45 —	.50
Chrome ore, 50% Cr_2O_3, f.o.b. Atlantic seaboard	unit	.45 —	.50
Coke, foundry, f.o.b. ovens	net ton	4.00 —	4.50
Coke, furnace, f.o.b. ovens	net ton	3.25 —	3.75
Coke, petroleum, refinery, Atlantic seaboard	net ton	15.00 —	16.00
Fluorspar, lump, f.o.b. mines, New Mexico	net ton	15.00 —	....
Fluorspar, standard, domestic washed gravel Kentucky and Illinois mines	net ton	20.00 —	22.50
Ilmenite, 52% TiO_2, per lb. ore	lb.	.01¼ —	.01½
Manganese ore, 50% Mn, c.i.f. Atlantic seaport	unit	.25 —	....
Manganese ore, chemical (MnO_2)	gross ton	60.00 —	65.00
Molybdenite, 85% MoS_2, per lb. of MoS_2, N. Y.	lb.	.55 —	.60
Monazite, per unit of ThO_2, c.i.f., Atlantic seaport	unit	30.00 —	....
Pyrites, Spanish, fines, c.i.f., Atlantic seaport	unit	.14 —	.14
Pyrites, Spanish, furnace size, c.i.f. Atlantic seaport	unit	.14 —	.14
Pyrites, domestic, fines, f.o.b. mines, Ga.	unit	.12 —	.13
Rutile, 95% TiO_2 per lb. ore	lb.	.15 —	....
Tungsten, scheelite, 60% WO_3 and over, per unit of WO_3 (nominal)	unit	2.75 —	3.00
Tungsten, Wolframite, 60% WO_3 and over, per unit of WO_3, N. Y. C.	unit	3.00 —	3.25
Uranium ore (carnotite) per lb. of U_3O_8	lb.	1.50 —	2.50
Uranium oxide, 96% per lb. contained U_3O_8	lb.	2.25 —	2.50
Vanadium pentoxide, 99%	lb.	12.00 —	14.00
Vanadium ore, per lb. of V_2O_5 contained	lb.	1.50 —	....
Zircon, washed, iron free	lb.	.03 —	....

Non-Ferrous Metals

New York Markets

	Cents per Lb.
Copper, electrolytic	13.00–13.25
Aluminum, 98 to 99 per cent	28.0@28.5
Antimony, wholesale lots, Chinese and Japanese	5½
Nickel, ordinary (ingot)	41.00
Nickel, electrolytic	44.00
Monel metal, spot and blocks	35.00
Monel metal ingots	38.00
Monel metal, sheet bars	40.00
Tin, 5-ton lots, Straits	29.50
Lead, New York, spot	4.50–4.75
Lead, E. St. Louis, spot	4.50
Zinc, spot, New York	4.85
Zinc, spot, E. St. Louis	4.45

OTHER METALS

Silver (commercial)	oz.	$0.58½
Cadmium	lb.	1.00–1.25
Bismuth (500 lb. lots)	lb.	1.50@1.55
Cobalt	lb.	4.00
Magnesium (f.o.b. Philadelphia)	lb.	1.25
Platinum	oz.	75.00
Iridium	oz.	250.00@275.00
Palladium	oz.	70.00
Mercury	75 lb.	46.00–47.00

FINISHED METAL PRODUCTS

	Warehouse Price Cents per Lb.
Copper sheets, hot rolled	20.50–20.75
Copper bottoms	28.00–28.25
Copper rods	19.25–20.00
High brass wire	18.25
High brass rods	15.25
Low brass wire	20.25
Low brass rods	20.25
Brazed brass tubing	29.00
Brazed bronze tubing	34.25
Seamless copper tubing	22.00
Seamless high brass tubing	21.00

OLD METALS—The following are the dealers' purchasing prices in cents per pound:

	New York Current	Cleveland	Chicago
Copper, heavy and crucible	9.25@9.50	9.25	9.50
Copper, heavy and wire	8.25@8.50	8.50	8.50
Copper, light and bottoms	7.25@7.75	7.50	7.25
Lead, heavy	3.25@3.50	3.25	3.75
Lead, tea	2.25@2.35	2.25	2.25
Brass, heavy	4.25@4.50	4.50	5.00
Brass, light	3.25@3.50	3.25	3.50
No. 1 yellow brass turnings	4.25@4.50	4.25	4.50
Zinc	2.00@2.50	2.00	2.25

Structural Material

The following base prices per 100 lb. aref or structural shapes 3 in. by ¼ in. and arger and plates ¼ in and heavier, from jobbers' warehouses in the cities named:

	New York	Cleveland	Chicago
Structural shapes	$2.60	$3.23	$3.23
Soft steel bars	2.50	3.00	3.13
Soft steel bar shapes	2.50	3.13	3.13
Soft steel bands	2.85	3.83	3.78
Plates, ¼ to 1 in. thick	2.50	3.30	3.23

*Add 15c per 100 lb. for trucking to Jersey City and 10c for delivery in New York and Brooklyn

Industrial

Financial, Construction and Manufacturers' News

Construction and Operation

California

FRESNO—The Fresno Tire & Rubber Co., has awarded a contract to the Unit Construction Co., Phelan Bldg., San Francisco, for the erection of a 3-story automobile tire and rubber goods manufacturing plant at Tehama and Belmont Aves., to cost about $200,000 with machinery. S. H. Christian, sales manager, is in charge.

SACRAMENTO—The United States Electric Steel Products Co., Inc., is planning for the erection of a new plant at Sacramento, and has acquired a large tract of land for this purpose. According to a statement from officials of the Chamber of Commerce, Vallejo, Cal., the company is planning for the erection of a branch plant on the Vallejo waterfront. Headquarters of the company are at San Francisco; it is capitalized at $50,000,000. The Electric Furnace Construction Co., 908 Chestnut St., Philadelphia, Pa., is interested in the project, and will handle the electric furnace installations at the plants. It is said that the main Sacramento works will cost about $5,000,000.

SAN MATEO—The Illinois-Pacific Glass Co., Fifteenth and Folsom Sts., San Francisco, is negotiating with the Chamber of Commerce, San Mateo, for a suitable site for the erection of a new local plant for the manufacture of glass products.

Connecticut

WATERBURY—The Scovill Mfg. Co., East Main St., manufacturer of brass products, has filed plans for the erection of a 1-story brick plant addition, 49 x 96 ft., to cost about $15,000.

WINDSOR—The Apothecaries Hall Co., 24 Benedict St., has awarded a contract to the Clark Construction Co., 168 Grand St., Waterbury, Conn., for the erection of a new 1-story fertilizer manufacturing and mixing plant, 64 x 140 ft., to cost about $27,000. William Stall is head.

NORWALK — Charles H. Harris, Inc., 136 West 24th St., New York, has awarded a contract to Levering & Garrigues, 552 West 23d St., for the erection of a new 1-story plant on Main St., 100 x 200 ft., for the manufacture of glass for automobile windshields. The new plant will cost about $75,000. Charles H. Harris is president.

Florida

LAKE WORTH—The Florida Sugar & Food Products Co., 110 South Dearborn St., Chicago, Ill., F. E. Bryant, president and manager, is perfecting plans for the erection of its proposed new sugar mill in the vicinity of Lake Worth to be 100x200 ft., with equipment to provide for an initial daily capacity of 500 tons of cane sugar. N. K. Williams, Canal Point, Fla., is construction engineer for the project.

Illinois

CHICAGO—The By-Products Coke Corp., 332 South Michigan Ave., has arranged for a bond issue of $4,000,000 for operations, financing, etc. H. H. S. Handy is president.

BLOOMINGTON — The Illinois Oakoal Corp., Bryant Bldg., Kansas City, Mo., has awarded a contract to the Frank P. McClure Construction Co., Kansas City, for the erection of its proposed new plant at Bloomington, estimated to cost about $100,000 with equipment.

CHICAGO—William J. Korber & Co., 413 North Carpenter St., operating a general iron works, have taken construction bids for a 1-story addition, 50x110 ft., on California St., to cost about $12,000. William J. Korber is head.

Indiana

COLUMBUS—The Indiana Oil Refining Co. has awarded a contract to the Graver Corporation, East Chicago, Ind., for the erection of its proposed new local oil refinery, consisting of a first plant unit, estimated to cost about $120,000. It is proposed to have the plant ready for operation in the fall.

SOUTH BEND—The Odell Rubber Co., recently organized with a capital of $50,000, is planning for the erection of a new plant for the manufacture of automobile tires at Paducah, Ky.

TERRE HAUTE—The American Car & Foundry Co. has plans under way for the rebuilding of the section of its local plant, recently destroyed by fire with loss of about $150,000, including equipment.

Kansas

WICHITA — The Wichita Dehydration Co., 616 Mutual Bank Bldg., has broken ground for the erection of a new 1-story and basement deyhdration plant, with initial capacity of about 50 tons per day, estimated to cost about $50,000 with equipment. T. C. Naylor, 311 Beacon Bldg., is the contractor. J. H. Elem is president.

Kentucky

SCOTTSVILLE — The Massey Refining Co. is planning for the erection of a new oil refinery, with initial capacity of about 500 bbl. per day. S. H. Massey and L. R. McKee head the company.

Maryland

BALTIMORE — The Virginia-Carolina Chemical Co., 11 South Twelfth St., Richmond, Va., is considering the construction of a new fertilizer manufacturing plant at Baltimore, with main building 100x200 ft., estimated to cost in excess of $2,500,000. S. D. Grenshaw is secretary.

BALTIMORE—The Holtite Mfg. Co., 919 East Baltimore St., has awarded a contract to R. B. Mason, 308 West Madison St., for the erection of its proposed new local plant, 50x142 ft., for the manufacture of rubber specialties, estimated to cost about $58,000, and of which amount approximately $30,000 will be used for equipment. Albert A. Esterson is secretary and treasurer.

CUMBERLAND—The Queen City Brick & Tile Co. is making extensions and improvements in its plant for increased production. The company recently increased its capital from $100,000 to $200,000. Henry J Glick is president.

BALTIMORE—The American Sugar Refining Co., 117 Wall St., New York, N. Y., has filed plans for the main refinery unit at its new local plant at Woodall and Clements Sts., to be 9-story, 60x164 ft. Stone & Webster, 120 B'way, New York, have the building contract.

Massachusetts

BROCKTON—George Baker & Sons, Inc., 103 Belmont St., manufacturer of nails, studs, staples, etc., will occupy the new 1- and 2-story plant, 83x223 ft., to be erected by the Baker Realty Co., an affiliated organization, on North Monticello St. It will cost about $75,000. George Howard & Sons, Inc., 633 Warren St., is the contractor.

Michigan

MONROE—The River Raisin Paper Co. has placed the first unit of its new local plant in operation, consisting of a building section 60 to 80 ft. x 720 ft., with capacity of about 60 tons per day. The new unit will be used primarily for the manufacture of corrugated strawboard. The entire plant of the company as now designed will develop an output of about 700,000 lb. of stock per day, and will give employment to approximately 1,500 operatives.

Missouri

CHILLICOTHE—The Moonshine Mfg. Co. has preliminary plans under way for the erection of a new plant for the manufacture of lubricants, cleaners, etc.

SELIGMAN—The Silver Lake Mining Co. is planning for the installation of new mining machinery and operating equipment at its local silver mines. A large new acreage will be developed. T. R. Gilliam is vice-president.

KANSAS CITY—A. W. Estabrook, 729 Holmes St., has construction under way on a new chemical laboratory, 2-story and basement, 40x60 ft., estimated to cost about $15,000.

ST. LOUIS — The Missouri Chemical Works, 1501 South Second St., is reported to be planning for the rebuilding of the portion of its plant, recently destroyed by fire, with loss estimated at $50,000. Arthur G. Whittaker is secretary.

LEEDS—The National Lumber & Creosoting Co., Houston, Tex., is planning for the establishment of a new creosoting plant at Leeds, with annual capacity of about 40,000,000 ft. of material.

KANSAS CITY—The Kansas City Wire & Iron Works is planning for the rebuilding of the portion of its plant recently destroyed by fire with loss estimated at $80,000.

New Jersey

NEWARK—John Campbell & Co., New York Ave., manufacturer of bookbinders' materials, leather, etc., have filed plans for extensions and improvements in their refinery to cost about $10,000.

New York

NEW YORK—The Pierce Oil Corp., 25 Broad St., is planning for a bond issue of $12,000,000, the proceeds to be used for expansion, refinery extensions, operations, etc.

North Carolina

WILMINGTON—The Shepard Chemical Co. is reported to be planning for the rebuilding of the portion of its plant recently destroyed by fire. E. C. Dickinson is head.

Oklahoma

BEGGS—The Taylor Oil & Gas Co., Okmulgee, Okla., is planning for the erection of a new two-unit compression gasoline plant in the vicinity of Beggs.

ARDMORE—The Cameron Refining Co. has commenced enlargements at its plant, to increase the capacity from 3,000 to 4,000 bbl. per day.

BARTLESVILLE—The Chamber of Commerce, E. L. George, secretary, is developing plans for the establishment of a new local plant for the manufacture of automobile tires and rubber goods.

Pennsylvania

BUTLER—The Valvoline Oil Co. is planning for the rebuilding of its local works, destroyed by fire May 29, with loss estimated at about $400,000, including equipment and stock.

PHILADELPHIA — Samuel McDowell, 1215 Filbert St., manufacturer of chemicals, has taken title to a plant building at Girard Ave. and 59th St., on site 178x223 ft., to be used in connection with local operations. The structure was used formerly by the Providence Worsted Mills.

Tennessee

CHATTANOOGA—The Ocoee Copper Co. is planning for the erection of a new flotation plant in the vicinity of Ducktown, Tenn., with initial capacity of about 300 tons per day, and estimated to cost about $200,000. P. B. Carter is secretary and treasurer.

Texas

BETHANY—J. B. Haynes, Houston, Tex., and associates are organizing a company to construct a large plant in the vicinity of Bethany for the manufacture of carbon black. It is proposed to utilize natural gas from the oil wells in this district for the new works, and application for permission to carry out the plans has been made to the State Railroad Commission.

TEMPLE—The T. S. Huddleston Mining Co., Belton, Tex., is planning for the establishment of a new works in the vicinity of Temple for the production of fullers earth. The company has extensive deposits in this section.

Virginia

WINCHESTER — The Cornwall Lime Marl Co., Romney, W. Va., has plans under way for the erection of a new plant for lime production in the vicinity of Winchester, with initial capacity of about 125 tons of material per day. The company will develop extensive lime marl deposits in this district. John J. Cornwall is president.

Wisconsin

SOUTH MILWAUKEE — The Bucyrus Co., manufacturer of excavating machinery, is taking bids for the erection of a new 1-story addition to its iron foundry, 66x220 ft.

Capital Increases, Etc.

THE ALUMINUM CHEMICAL CO., Chicago, Ill., has filed notice of increase in capital from $100,000 to $200,000.

THE CHAMPLAIN PULP & PAPER CORP., Saratoga Springs, N. Y., has filed notice of dissolution under state laws.

THE ANSBACHER INSECTICIDE CO., 527 Fifth Ave., New York City, has filed notice of increase in capital from $10,000 to $150,000.

THE A. H. ANDERSON FOUNDRY CO., 218 Ann St., Chicago, Ill., manufacturer of brass castings, etc., has filed notice of increase in capital from $5,000 to $100,000.

THE ROWELL OIL MILLS CO., Bastrop, Tex., manufacturer of cottonseed oils, etc., has filed notice of increase in capital from $27,000 to $75,000.

THE LONG ISLAND BRICK CO., 280 Madison Ave., New York City, with brick manufacturing plant at Farmingdale, L. I., has filed notice of increase in capital to $800,000.

THE LYSTER CHEMICAL CO., 61 B'way, New York City, has filed schedules in bankruptcy with liabilities stated as $184,458, and assets as $98,180.

THE ROOSEVELT DRUG & CHEMICAL CO., 117-19 Smith St., Perth Amboy, N. J., has filed notice of dissolution under state laws.

THE AMERICAN SILICA PRODUCTS CO., Indianapolis, Ind., has filed notice of dissolution under state laws.

THE MONARCH-NUSBAUM PAPER BOX CO., 106 B'way., Buffalo, N. Y., has filed notice of increase in capital from $10,000 to $150,000.

THE MILES FIBER PRODUCTS CO., Chicago, Ill., has filed notice of increase in capital from $20,000 to $60,000.

THE HOSKIN-MORAINVILLE PAPER CO., Menominee, Mich., has filed notice of increase in capital from $750,000 to $1,000,000.

New Companies

THE NORMAL APPARATUS CO., 217-23 West Huron St., Chicago, Ill., has been incorporated with a capital of $15,000 to manufacture chemicals and affiliated products. The incorporators are Carl F. W. Pfeiffer, Charles J. Deegan and E. Merckle.

THE ATLANTIC TANNING EXTRACT CO., New York City, has been incorporated under New Jersey laws, with capital of 2,500 shares of stock, to manufacture synthetic extracts for tanning and kindred products. The company is represented by Arthur W. Britton, 65 Cedar St.

THE AMERICAN METALLURGICAL CORP., Boston, Mass., has been incorporated with a capital of $50,000 to operate a metallurgical works. Harry O. Breaker is president, and Kristian A. Juthe, Newton Center, Mass., treasurer.

THE EASTERN CHEMICAL CO., Boston, Mass., has been incorporated with a capital of $50,000 to manufacture chemicals and chemical byproducts. Henry A. Smith is president, and Joseph J. McCloskey, 294 Washington St., treasurer.

THE NEW JERSEY LITHO & PRINTING INK CO., East Rutherford, N. J., has been incorporated with a capital of $25,000 to manufacture inks. The incorporators are Frederick Prinzing, John F. Laverty and Albert E. Williams, East Rutherford.

THE EAGLE CONVEX GLASS SPECIALTY MFG. CO., Clarksburg, W. Va., has been incorporated with a capital of $50,000 to manufacture glass products. The incorporators are Edgar Forneus and Frank Aucremanne, Clarksburg.

THE FI-BISTOS MFG. CO., New York City, has been incorporated with a capital of $100,000 to manufacture chemicals and chemical byproducts. The incorporators are H. H. Blackmer, G. Pantzer and D. C. Godwin, 165 West 31st St.

THE NATIONAL CASEIN CO., 613 West 80th St., Chicago, Ill., has been incorporated with a capital of $15,000 to manufacture glues and kindred products. The incorporators are Richard P. Poulton, Joseph A. Rogers and William E. Rodrigues.

THE STONE FORT OIL CO., Houston, Tex., has been incorporated with a capital of $150,000 to manufacture petroleum products. The incorporators are Taylor J. Hughes, T. P. Griffin and V. F. Nehaus, Houston.

J. E. TEMPLETON & CO., INC., Westfield, Mass., has been incorporated with a capital of $20,000 to manufacture chemicals, oils, etc. Louis M. Fuller is president; and James E. Templeton, Westfield, treasurer.

THE NEW ENGLAND SMELTING WORKS, INC., Springfield, Mass., has been incorporated with a capital of $25,000 to manufacture metal products. Abraham J. Saffer is president, and Morris Levin, 119 Massasoit St., treasurer.

MIR, CODINA & MARQUES, INC., Jersey City, N. J., has been incorporated with a capital of $125,000 to manufacture cork products. The incorporators are Lewis Mir, Peter Codina and Michael Marques, 592 Montgomery St.

THE DARLING PRODUCTS, INC., Albany, N. Y., has been incorporated with a capital of $25,000 to manufacture compounds, baking powders and kindred specialties. The incorporators are F.E.B. and H. S. Darling, and A. Bonesteel, Albany. T. J. Quillinan, Troy, N. Y., represents the company.

THE A. A. NOE CHEMICAL CO., Rogersville, Tenn., has been incorporated with a capital of $15,000 to manufacture chemicals and chemical byproducts. A. A. Noe and J. L. Cunningham, Rogersville, head the company.

THE CRAFTEX OIL CO., Crafton, Pa., has been incorporated with a capital of $500,000 to manufactuure petroleum products. The incorporators are S. H. Fisher, H. C. Schada and A. T. Cushing, Crafton.

THE HUMMEL & ROBINSON CORP., New York City, has been incorporated with a capital of $100,000 to manufacture chemicals and chemical byproducts. The incorporators are J. C. Robinson, C. P. Swaffield and A. Hummel. The company is represented by G. J. Gruenberg, 320 B'way.

THE SOUTH JERSEY IRON FOUNDRY, INC., Pleasantville, N. J., has been incorporated with a capital of $10,000 to manufacture iron and steel castings. Wray C. Arnold, Commonwealth Bldg., Philadelphia, Pa., represents the company.

THE LANG-HORTON TANNING CO., INC., Hutton, Garrett Co., Md., has been incorporated with a capital of $100,000 to manufacture leather products. The incorporators are J. Harry Lang, Nathan Fried and LeRoy Morton, Hutton.

PHILLIPS & JAFFRAY, INC., New York City, has been incorporated with a capital of $25,000 to manufacture soluble oils, sizing, etc. The incorporators are H. C. Good, B. D. Phillips and S. L. Jaffray. The company is represented by J. W. Hyde, 29 B'way.

THE BRISTOL STOVE & FOUNDRY CO., INC., Bristol, Va., has been incorporated with a capital of $50,000 to manufacture iron and steel castings, etc. H. E. Wilkinson is president and J. C. Rucker, secretary, Bristol.

THE TANGHE BROTHERS CO., Detroit, Mich., has been incorporated with a capital of $25,000 to manufacture bricks and other burned clay products. The incorporators are R. M., Henry F. and Edward F. Tanghe, 1233 Pine St.

THE MOCHAR LEATHER GOODS CORP., New York City, has been incorporated with a capital of $15,000 to manufacture leather specialties. The incorporators are B. Charsky, W. E. Mock and H. J. Woronov. The company is represented by A. M. Bloch, 185 Madison Ave.

THE ARKANSAS CRUDE OIL CO., Little Rock, Ark., has been incorporated with a capital of $200,000, to manufacture petroleum products. The incorporators are Charles Leiger and E. W. Emerson, Little Rock.

THE RIVERSIDE FULLERS EARTH CO., Riverside, Tex., has been incorporated with a capital of $50,000 to operate a producing works for fullers earth and similar products. The incorporators are T. R. Buell, E. P. Darrigrand and S. C. Collins, Riverside.

THE ORION PAINT CO., New York City, has been incorporated with a capital of $10,000 to manufacture paints, varnishes, etc. The incorporators are C. D. Cregan, J. W. Linck and L. Bennett, 61 B'way.

THE BLUE GRASS PRODUCTION CO., 1504 Standard Trust Bldg., Chicago, Ill., has been organized to manufacture refined oil products. George B. Harker and A. S. Sorenson head the company.

THE PINEVILLE PETROLEUM CO., Pineville, Ky., has been incorporated with a capital of $40,000 to manufacture petroleum products. The incorporators are W. L. Moss and A. R. Anderson, Pineville.

THE CHEMICAL SERVICE & SALES CORP., New York City, has been incorporated with a capital of $15,000 to manufacture chemical specialties. The incorporators are E. Celler, M. Kraushaar and J. Maroona. Celler & Kraushaar, 51 Chambers St., represent the company.

HARRY L. IKE, INC., Dover, N. J., has been incorporated with a capital of $25,000 to manufacture paints, varnishes, etc. The incorporators are Harry L. Ike, Arthur V. Casterline and Herbert T. Hartley, Dover.

THE ALTO RUBBER CO., New York City, has been incorporated with a capital of $6,000 to manufacture rubber varnish, glues, and kindred products. The incorporators are R. Schliesel, S. Moore and H. Hewitt. The company is represented by S. D. Levy, 302 B'way.

THE MENDENHALL TORPEDO CO., Duncan, Okla., has been incorporated with a capital of $20,000 to manufacture explosives. The incorporators are G. L. Wilson, Duncan; W. B. Hamilton and T. W. Mendenhall, both of Wichita Falls, Tex.

THE TEXAS EAGLE OIL & REFINING CO., Fort Worth, Tex., has been incorporated with a capital of $25,000, to manufacture refined oil products. The incorporators are E. B. Eakle, and F. A. Cok, Fort Worth.

THE SCHAEFER DRUG CORP., New York City, has been incorporated with a capital of $50,000 to manufacture chemicals, drugs, etc. The incorporators are O. and E. W. Schaefer, and M. Boehringer. The company is represented by B. Swartz, 192 B'way.

THE HUDSON RIVER FOUNDRY CO., Poughkeepsie, N. Y., has been incorporated with a capital of $10,000 to manufacture iron and other metal castings. The incorporators are J. Hanson, H. B. Vosburgh and C. W. H. Arnold, Poughkeepsie.

THE MAURICE OIL CORP., Duncan, Okla., has been incorporated with a capital of $200,000 to manufacture petroleum products. The incorporators are W. E. Hawley, Duncan; and J. L. Hill, Wichita Falls, Tex.

THE RAE DRUG & CHEMICAL CO., Pittsburgh, Pa., is being organized by Joseph Davis, Harry J. Kane and N. Leivreri, to manufacture chemical products. The company is represented by Harrison Bock, 1412 Berger Bldg., Pittsburgh.

Coming Meetings and Events

AMERICAN CERAMIC SOCIETY'S summer meeting will be held at Canton, Alliance, Sebring and East Liverpool, Ohio, July 25 to 27. Headquarters will be at the Hotel Courtland, Canton, Ohio.

AMERICAN CHEMICAL SOCIETY, THE SOCIETY OF CHEMICAL INDUSTRY and the American Section of the latter society will hold a joint meeting in New York, Sept. 6 to 10.

AMERICAN ELECTROCHEMICAL SOCIETY will hold its fall meeting in Lake Placid, N. Y., Sept. 29 and 30, and Oct. 1.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS will hold its spring meeting June 20 to 24 at Detroit. Industrial excursions will be made to Ann Arbor, Saginaw, Midland and Bay City.

AMERICAN MINING CONGRESS AND NATIONAL EXPOSITION OF MINES AND MINING EQUIPMENT will hold its twenty-fourth annual convention in the Coliseum, Chicago, Oct. 17 to 22.

AMERICAN SOCIETY FOR STEEL TREATING will hold its third annual convention and exhibition Sept. 19 to 24 at Indianapolis.

AMERICAN SOCIETY FOR TESTING MATERIALS will hold its 1921 annual meeting in the New Monterey Hotel, Asbury Park, N. J., during the week of June 20. Technical sessions are scheduled as follows: Tuesday, on Preservative Coatings and Textiles; Wednesday, on Cement, Concrete and Road Materials; Thursday, on Ceramics, Lime and Gypsum, on Petroleum Products and on Testing Methods; Friday, on Metals.

THE NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES (SEVENTH) will be held during the week of Sept. 12 in the Eighth Coast Artillery Armory, New York City.

NATIONAL FERTILIZER ASSOCIATION will hold its twenty-eighth annual convention at the Greenbrier Hotel, White Sulphur Springs, W. Va., the week beginning June 20.

NATIONAL LIME ASSOCIATION is holding its annual convention in New York City June 15 to 17.

NEW JERSEY CHEMICAL SOCIETY holds a meeting at Stetters Restaurant, 842 Broad St., Newark, N. J., the second Monday of every month.

SOCIETY OF CHEMICAL INDUSTRY (BRITISH) at the invitation of the Montreal section will hold its annual meeting in Montreal and other Canadian cities during the week of Aug. 29, 1921. Details will be printed in this magazine from time to time.